Dynamical Evolution of Nearby galaxies from EDGE-CALIFA survey

by
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in collaboration with:

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+ CALIFA & EDGE teams

Max-Planck-Institut für Radioastronomie

CALIFA Survey

EDGE

AG meeting,
Stuttgart
September
16-20, 2019

Introduction

The Seyfert galaxy NGC 1097. Image ESO/R. Gendler.

Dynamical evolution of Galaxies

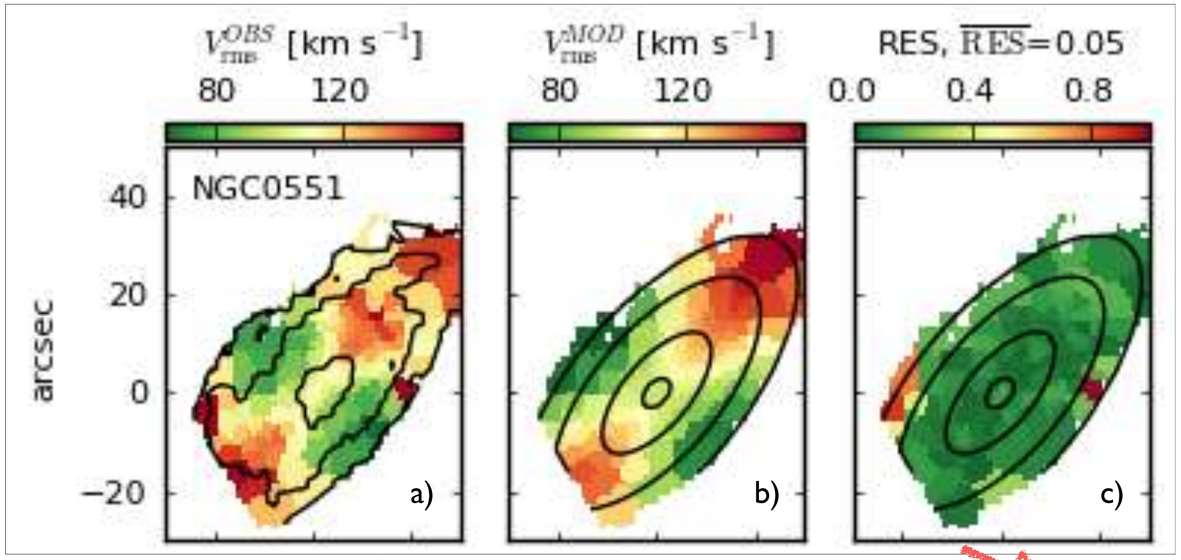
To understand how galaxies transform from one dynamical state to another we explore the connection between **internal dynamics** and **SF-quenching processes** in CALIFA and EDGE samples.

CALIFA survey (IFU survey, 667 galaxies): Sanchez et al. 2012

EDGE survey (CO follow-up of CALIFA, 126 galaxies): Bolatto et al. 2017

Dynamics across Hubble sequence

CALIFA data and dynamical model



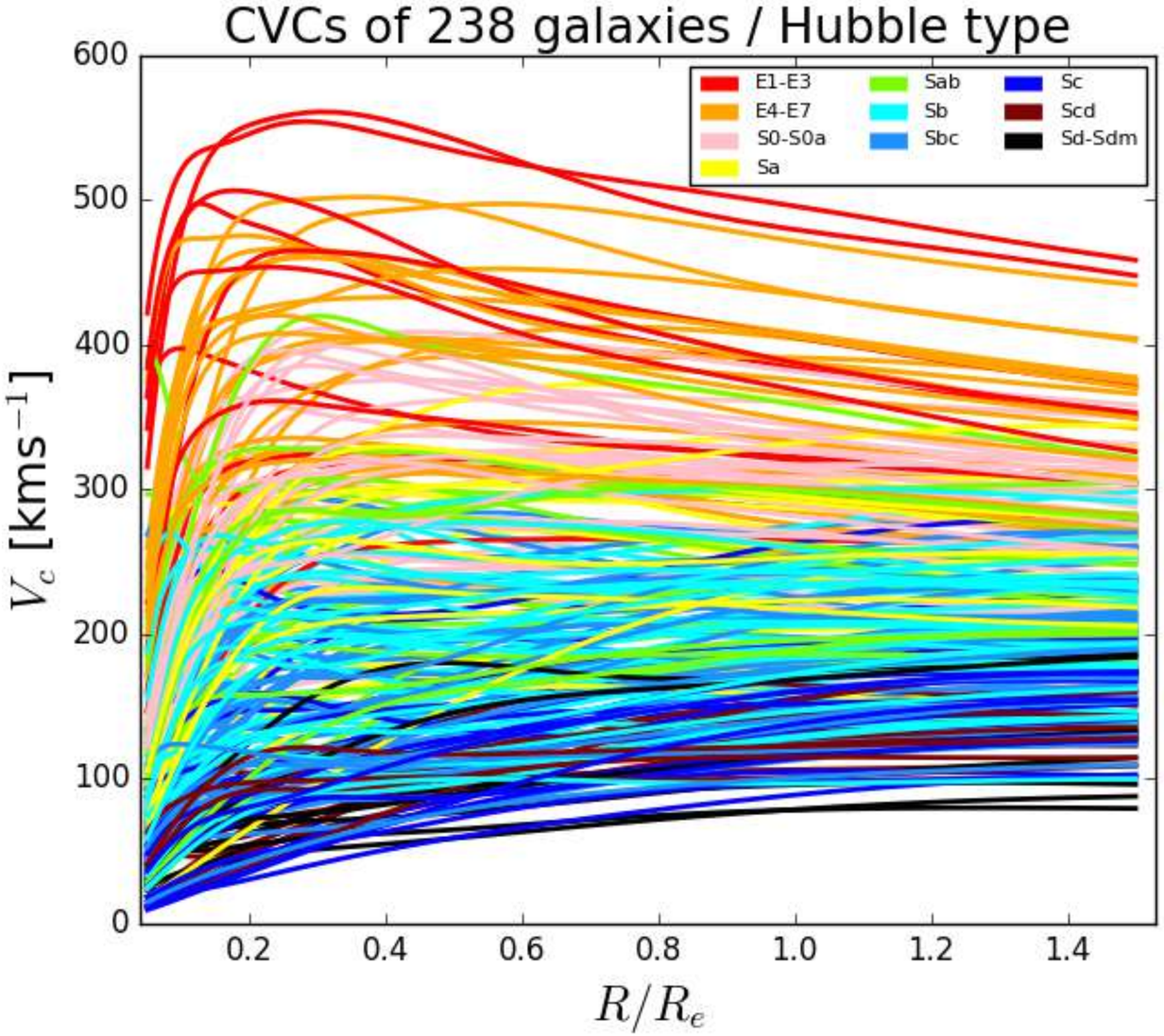
IFU observations

Dynamical model (JAM)

goodness of the fit

*SDSS Photometry + Fitting the second velocity moment (Vrms**2=V**2+σ**2) via MCMC —> modelling the gravitational potential of the galaxy —> obtaining CVC

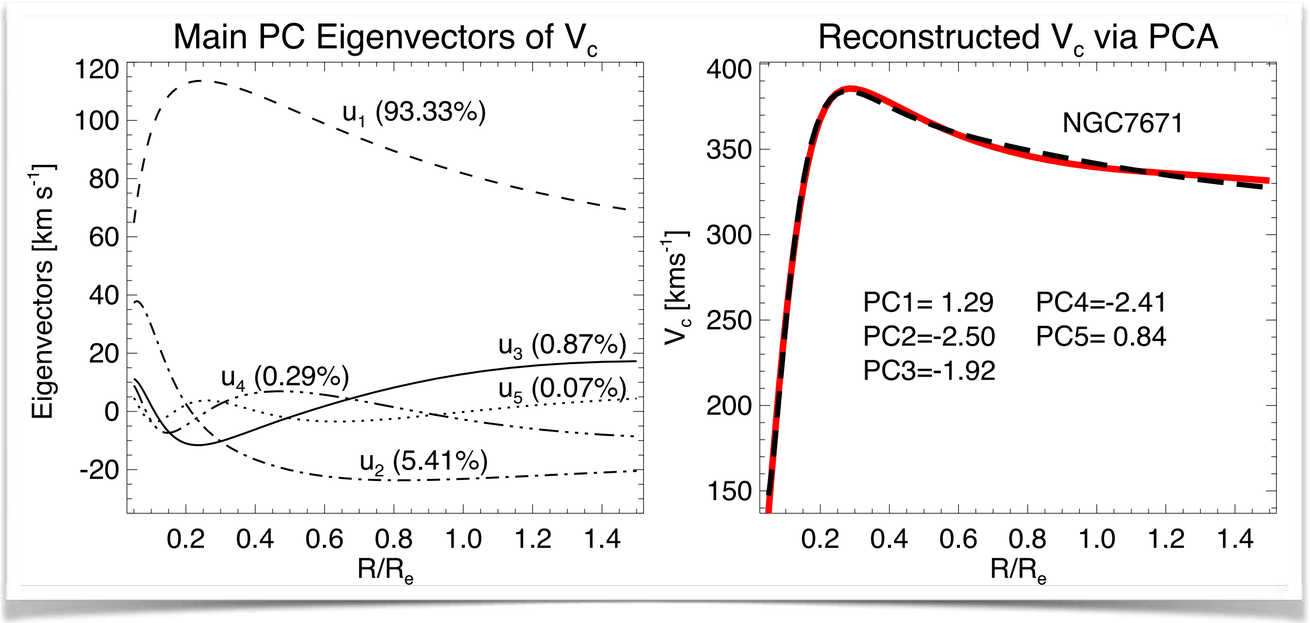
CALIFA survey: Sanchez+2012



*Derived Circular Velocity Curves (CVCs) of 238 CALIFA galaxies with various shapes and amplitudes

Kalinova et al., 2017, MNRAS, 469, 2539

Circular Velocity Curve (CVC) classification

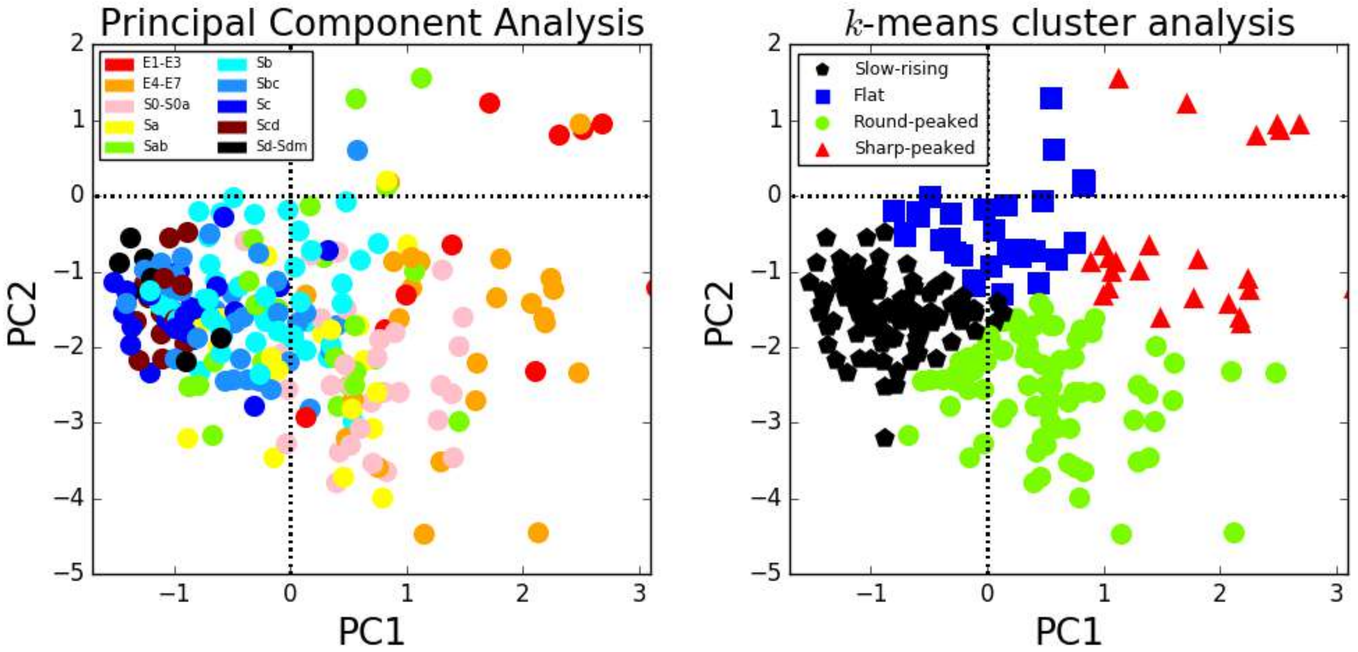


1) Principal Component Analysis (PCA)

Reconstruction of CVC:

$V_c = V_{c,mean} +$ PC1 • **u1** + PC2 • **u2** + PC3 • **u3** + PC4 • **u4** + PC5 • **u5**

u1 and **u2** - major contribution (∼99%)



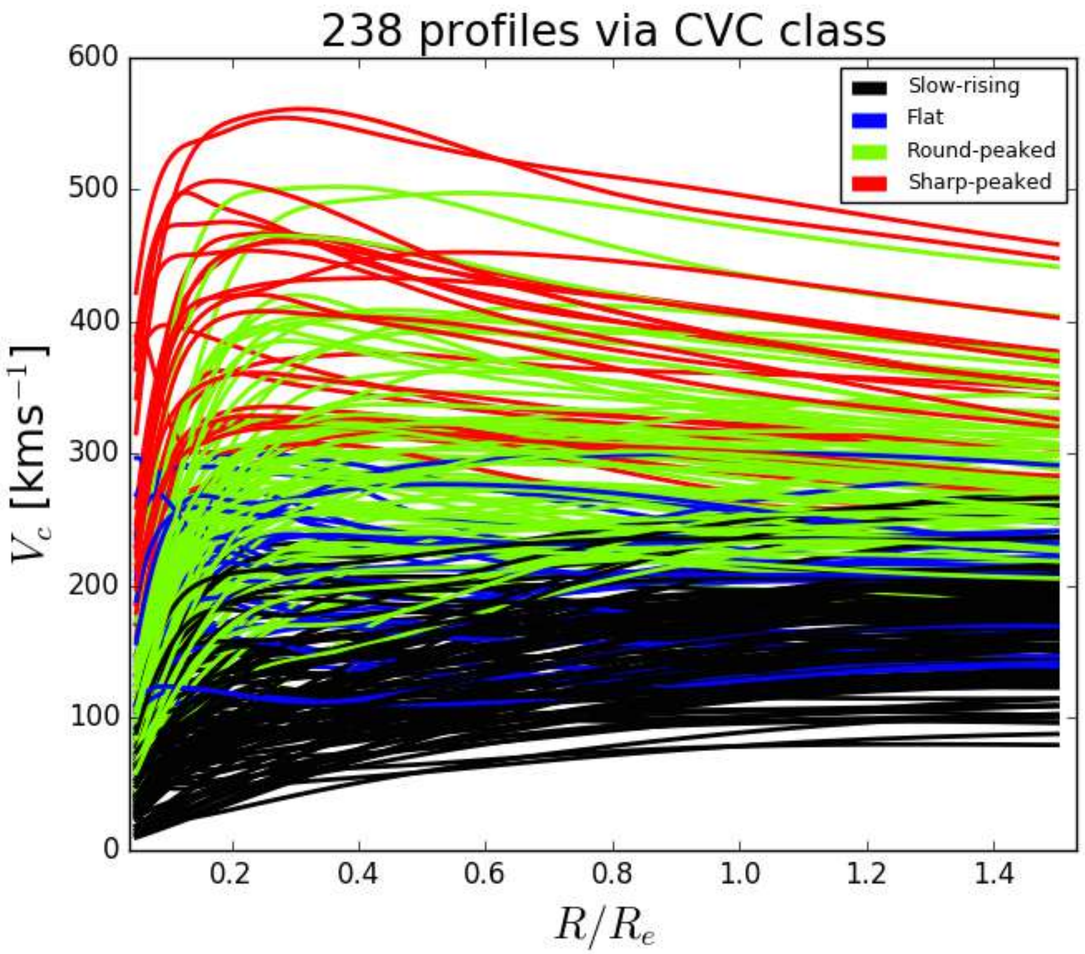
2) Clustering analysis

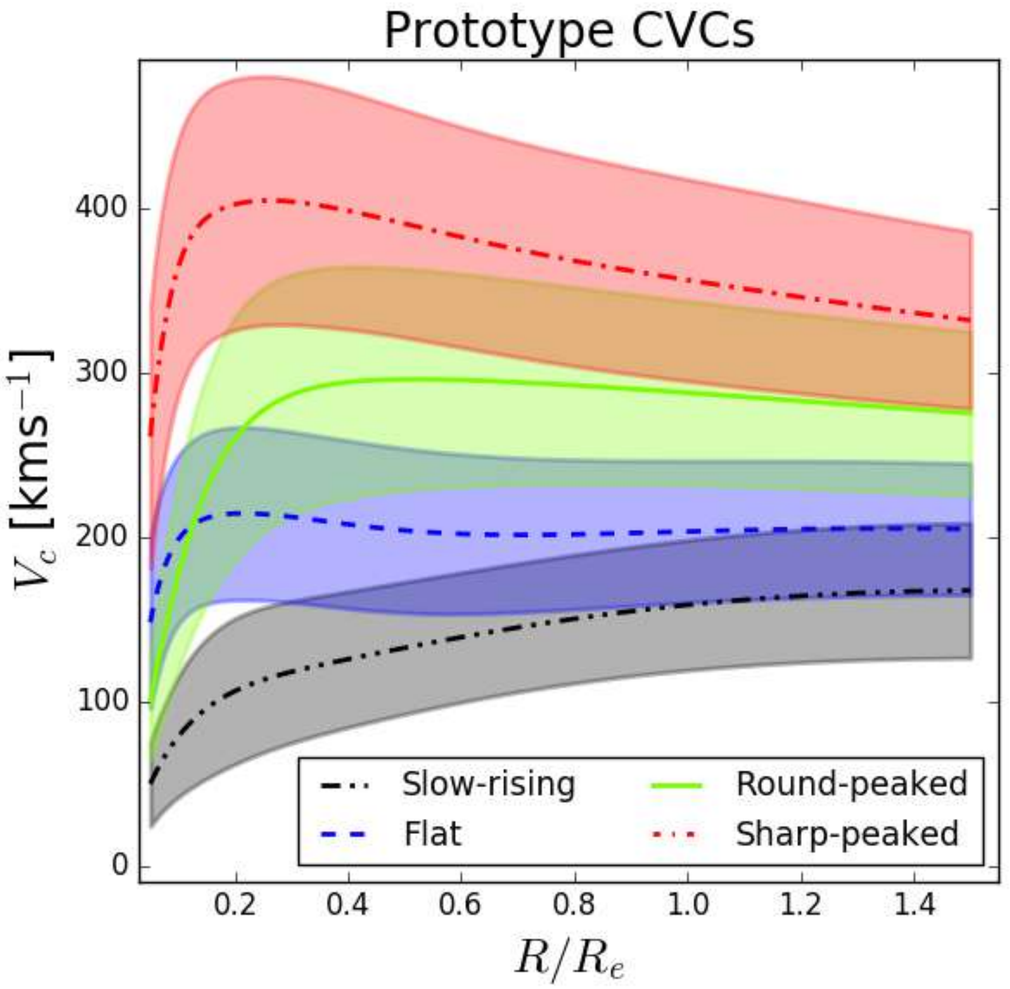
K-means clustering analysis on the PC1-PC2 plane through Hubble type (left) labels 4 groups of CVC profiles (right)

Each data point is assigned to its nearest centroid (center of the cluster), based on the squared Euclidean distance.

Kalinova et al., 2017, MNRAS, 469, 2539

CVC classes: Prototype curves



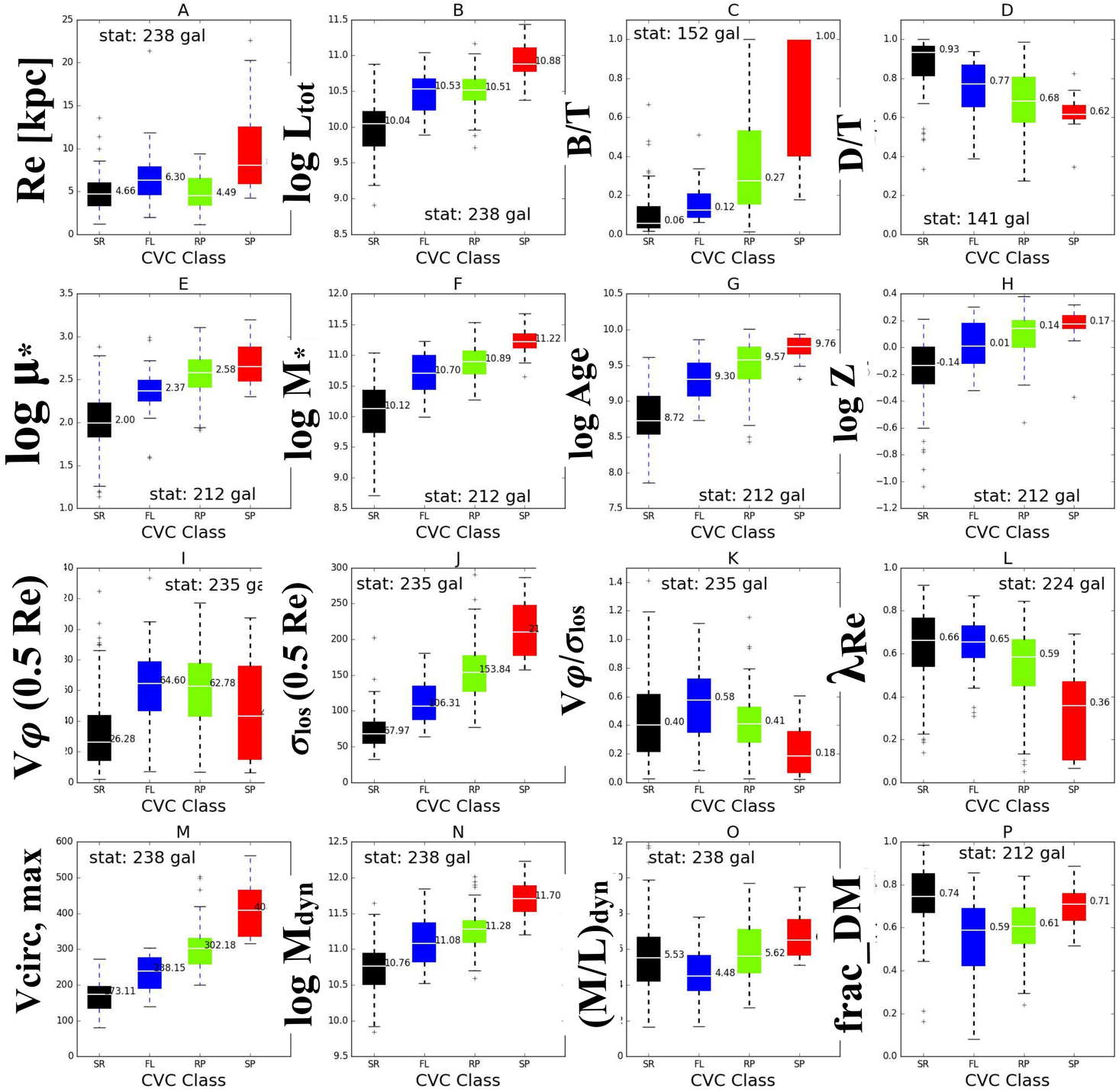


CVC Classification from early- to late-type galaxies after the application of PCA and k-means cluster technique

Kalinova et al., 2017, MNRAS, 469, 2539

***4 Prototype curves: Slow-rising (SR), Flat (FL), Round-peaked (RP), Sharp-peaked (SP) classes**

***CVC classes strongly reflect the degree of central mass concentration**



CVC class correlates with many properties of the galaxies

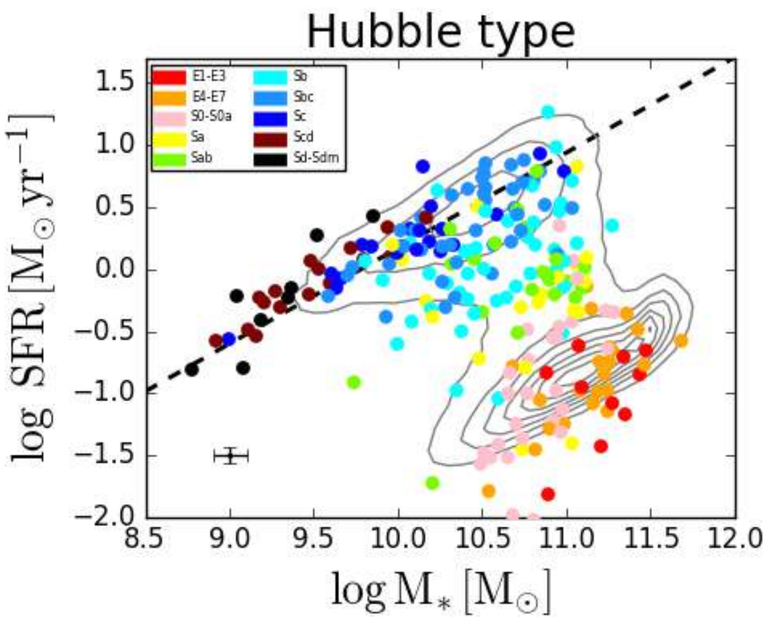
-Slow-rising CVCs are typical for low-mass, late-type (Sb–Sdm), young, faint, metal-poor, and disk-dominated galaxies

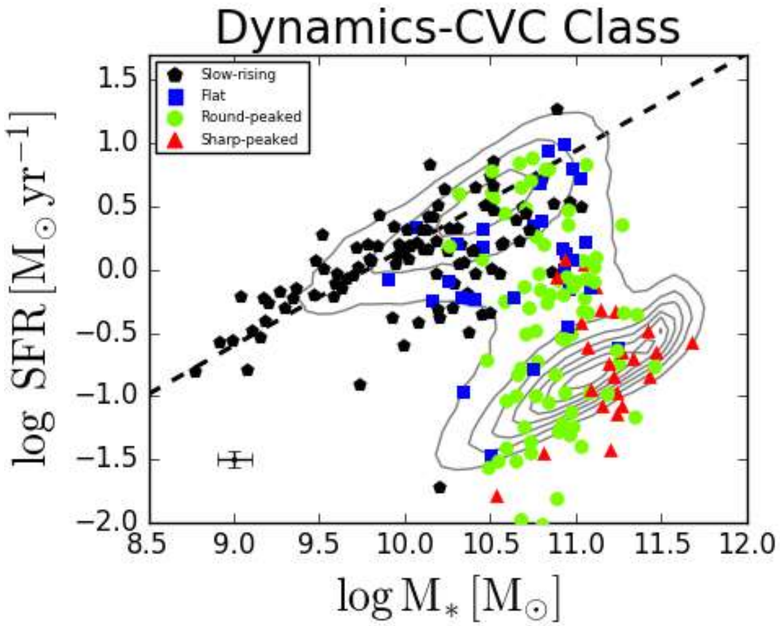
-Sharp-peaked CVCs are typical for high-mass, early-type (E1–E7), old, bright, metal-rich, and bulge-dominated galaxies

-Flat and Round-peaked appear presented by galaxies with intermediate properties

Kalinova et al., 2017, MNRAS, 469, 2539

SFR-M* diagram across Hubble sequence and CVC class



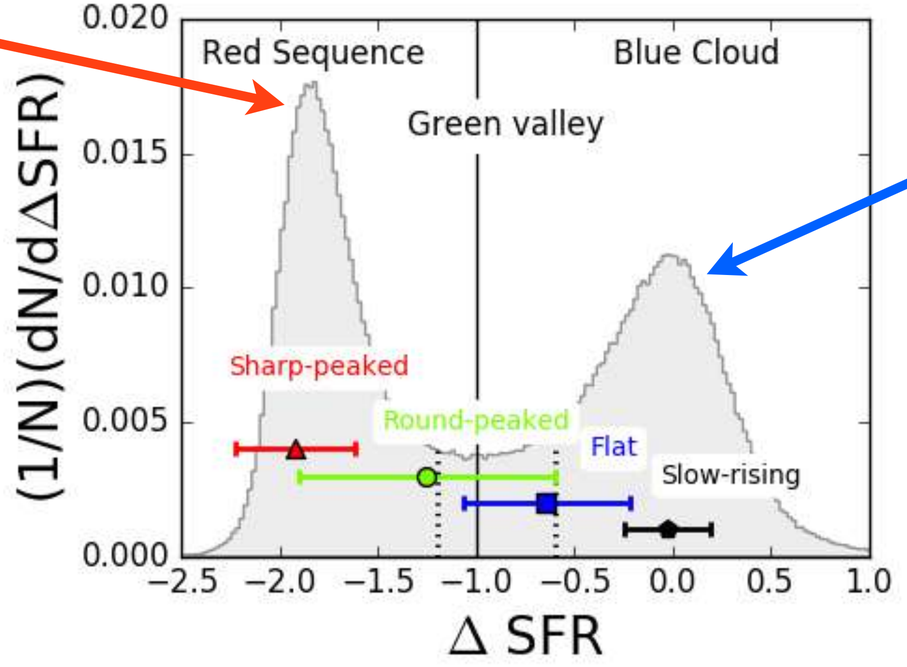


SFR, M* - stellar population model (Chabrier IMF, applied method from Gonzalez Delgado+2017)

Main Sequence (MS) fit: Elbaz+2007

SDSS contours: Kaufmann+2003, Brinchmann+2004, Salim+2007

Red sequence



Blue cloud

Sequential nature of the CVC classes:

Slow-Rising--> Flat--> Round-peaked-->Sharp-peaked

GREEN VALLEY boarders (dotted lines): Bluck+2016

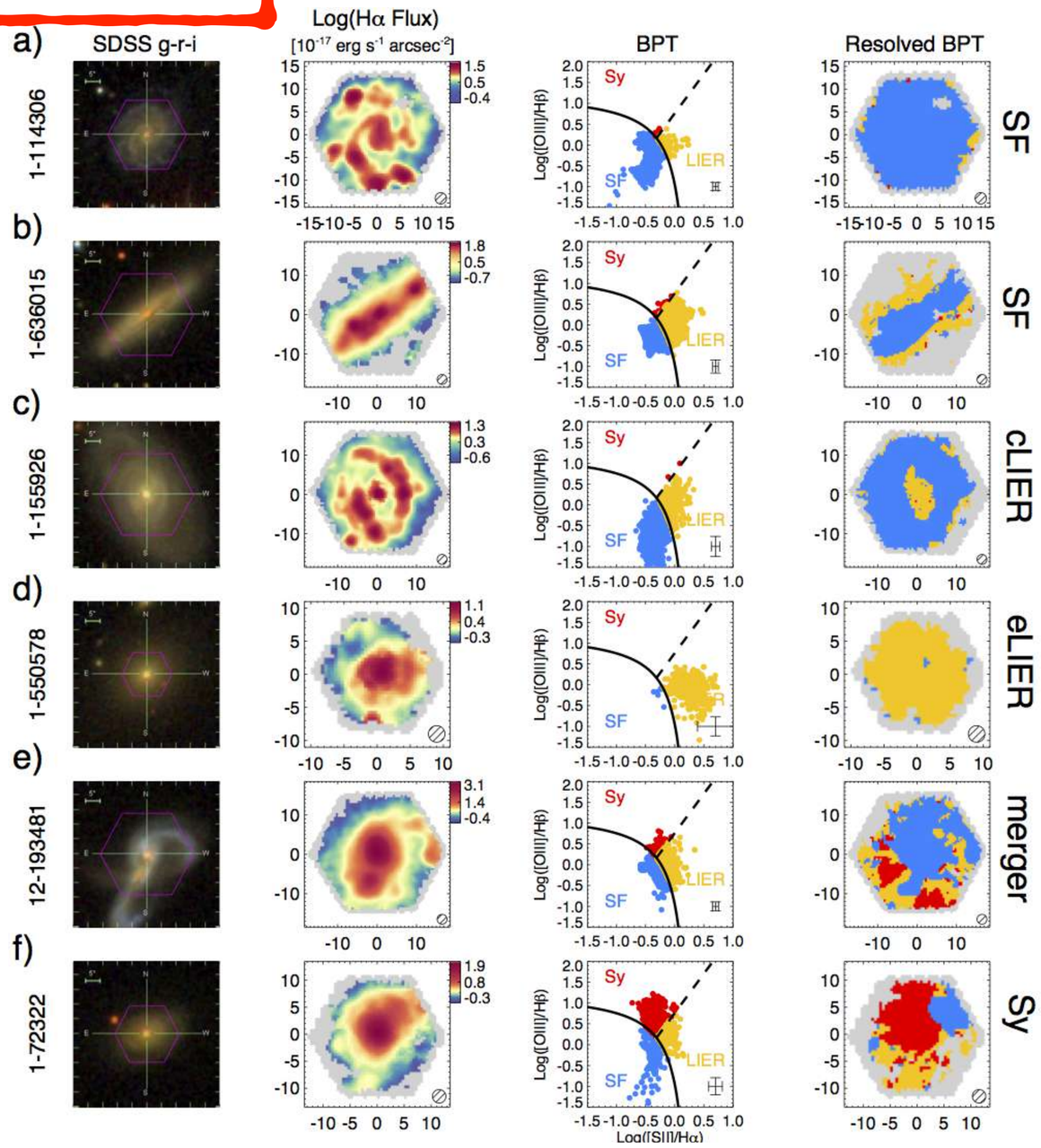
Grey area: Distribution of SDSS galaxies

ΔSFR: Log distance from the Main Sequence (MS)

Kalinova et al., in preparation

Emission-Line Classification (ELC) in the literature

Belfiore+2016



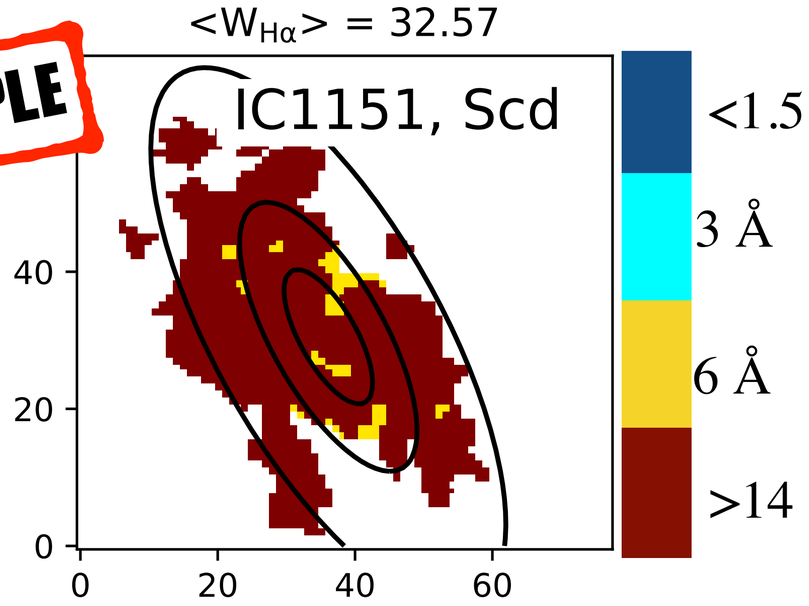
5 classes based on the resolved [SII]-BPT (Belfiore+2016):
star-forming (SF), central LIER (cLIER) ,
extended LIER (eLIER), merger, Seyfert (Sy)

LIER: Low Ionisation Emission-line Region

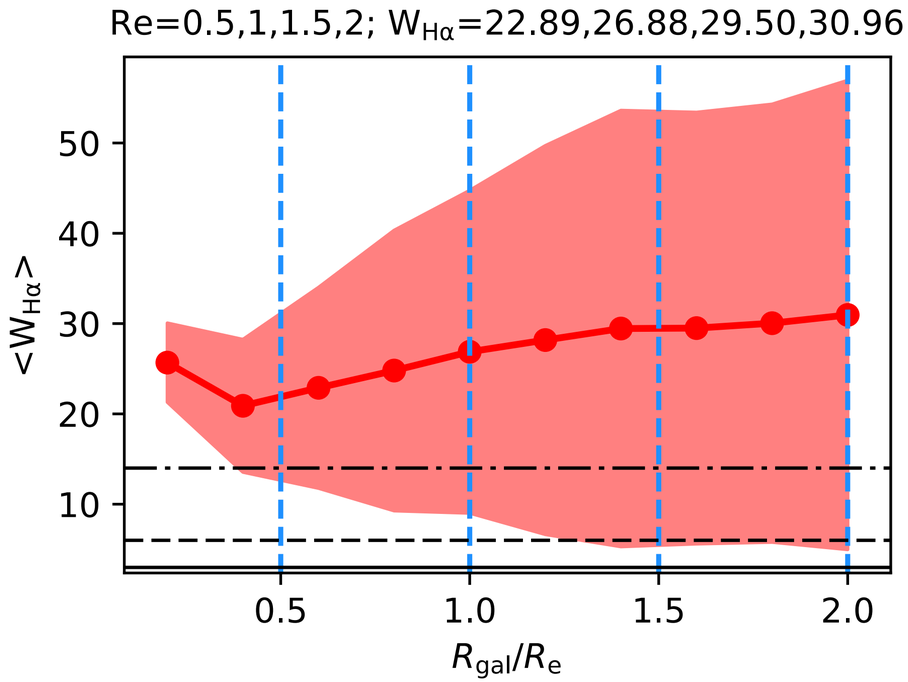
We performed ELC on the 238 CALIFA galaxies following similar criteria.

Few differences in our case:
-no mergers in this sample
-we use the three resolved [NII]-, [SII]-,[OIII]- maps and diagrams
-we distinguish between strong and weak AGN
-we adopt the $H\alpha$ -equivalent-width ($W_{H\alpha}$) criteria of Cid Fernandes+2011

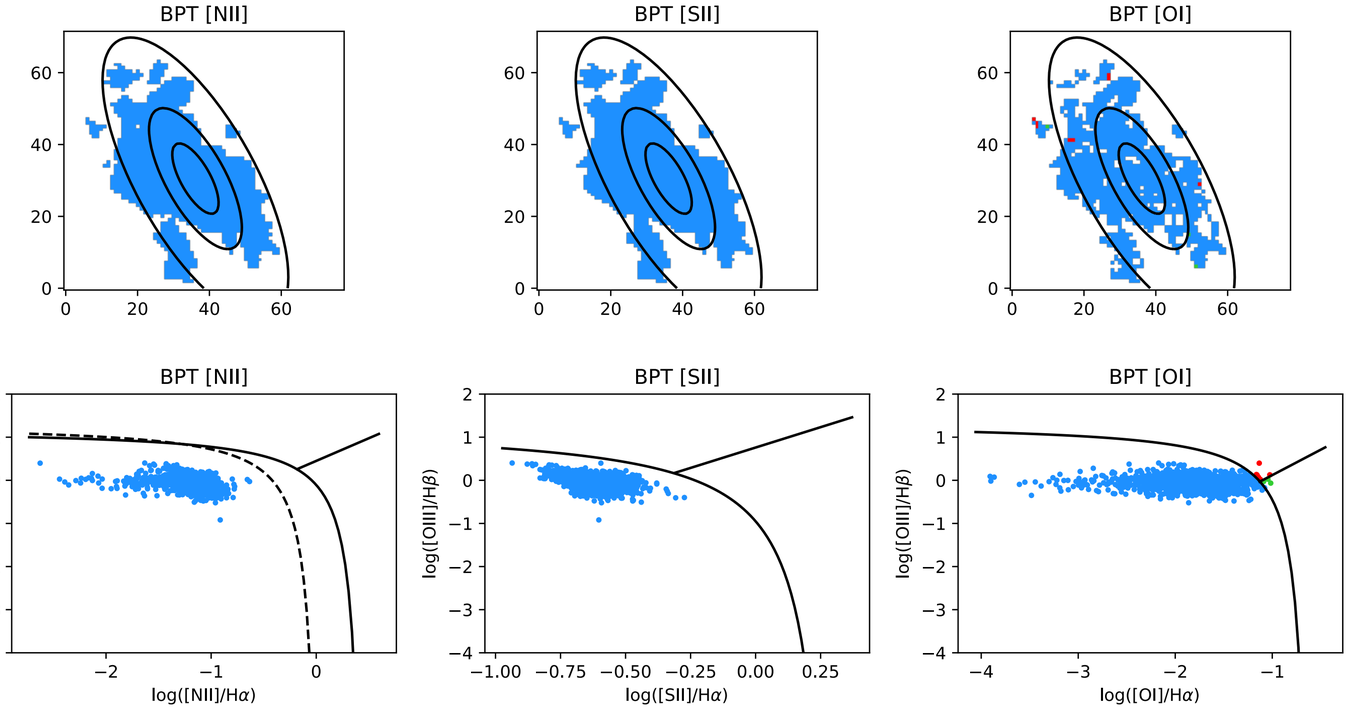
EXAMPLE



Star-forming



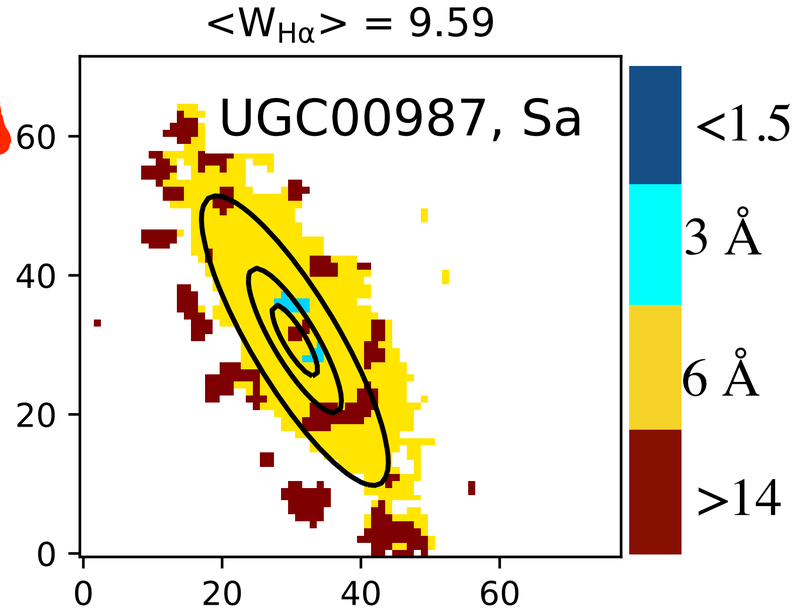
Spatially Resolved BPT maps and diagrams



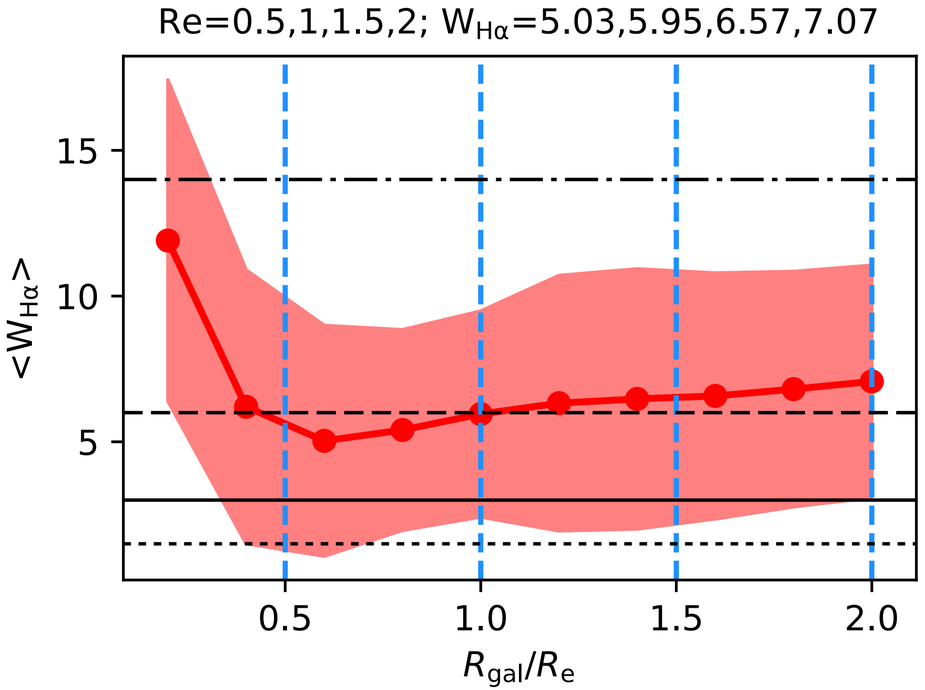
main criteria for SF:
$W_{H\alpha}$ - above 3 Å at all radii

Kalinova et al., in preparation

EXAMPLE



strong AGN



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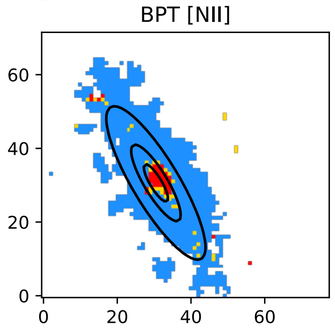
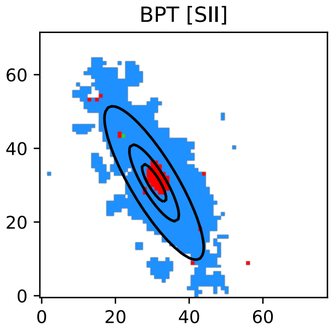
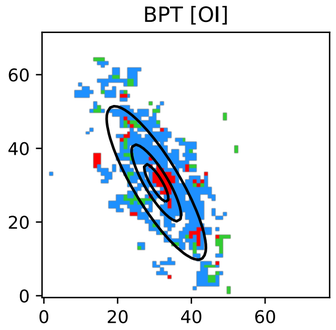
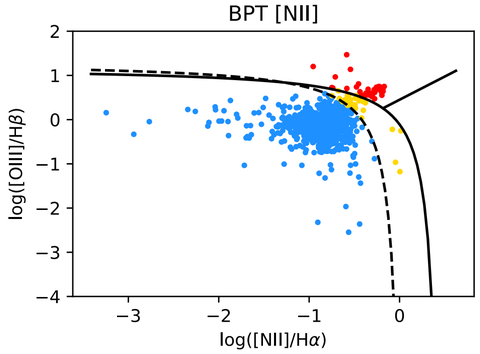
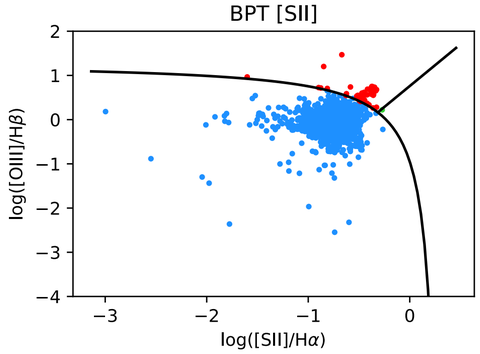
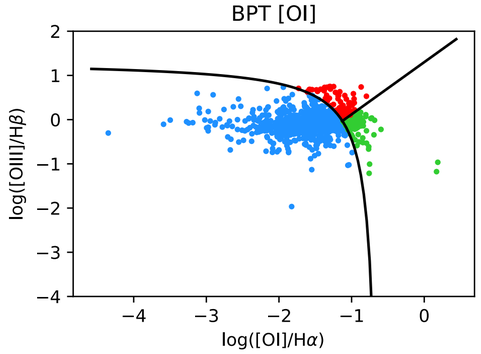










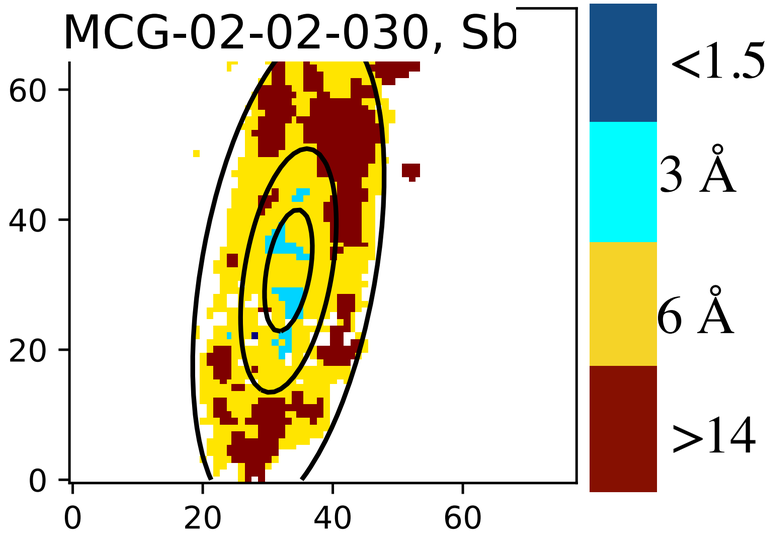


main criteria for sAGN:

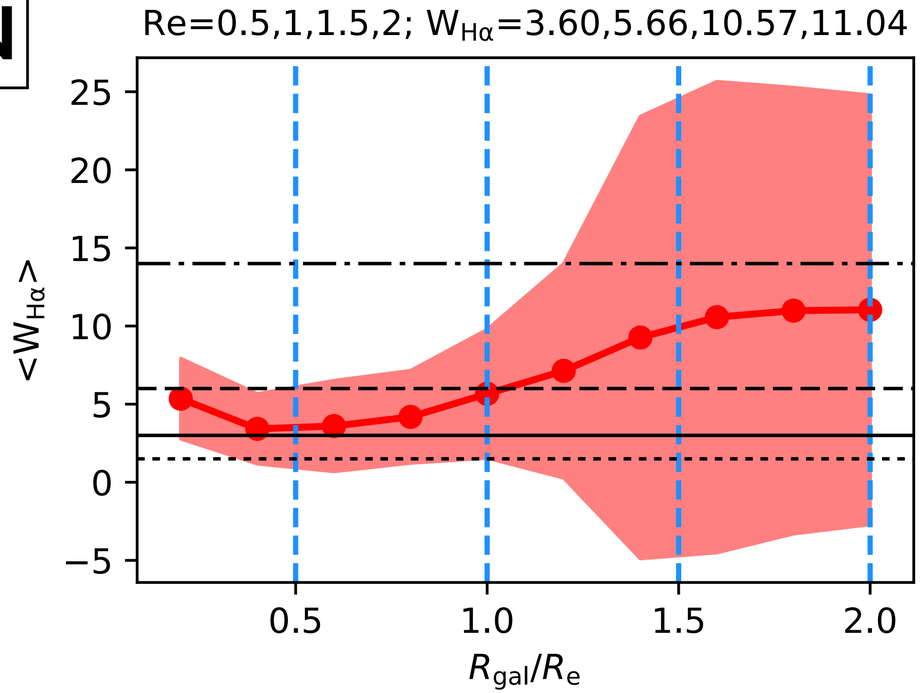
$W_{H\alpha}$ - above 6Å at $R_e < 0.5$

Kalinova et al., in preparation

EXAMPLE



weak AGN



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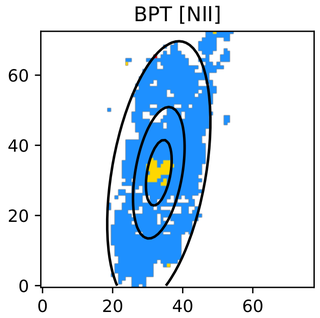
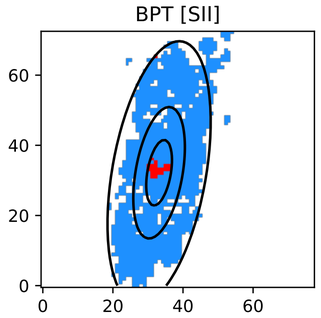
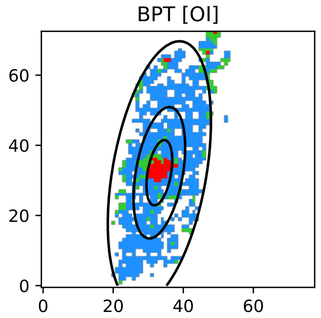
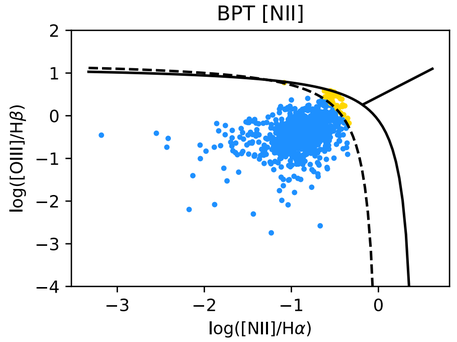
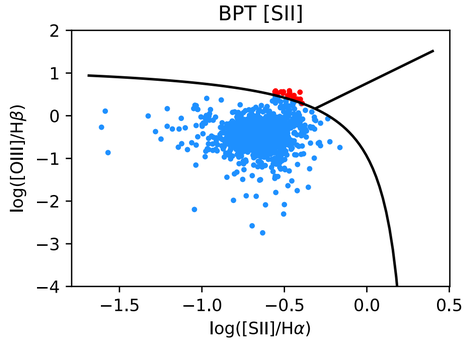
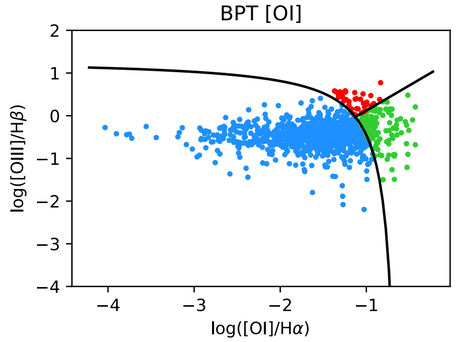












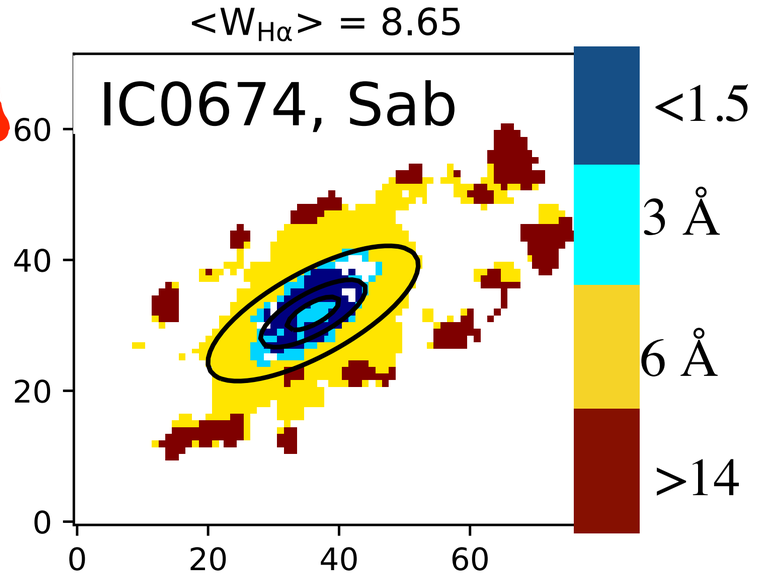
main criteria for wAGN:

$W_{H\alpha}$ - between 3Å and 6Å

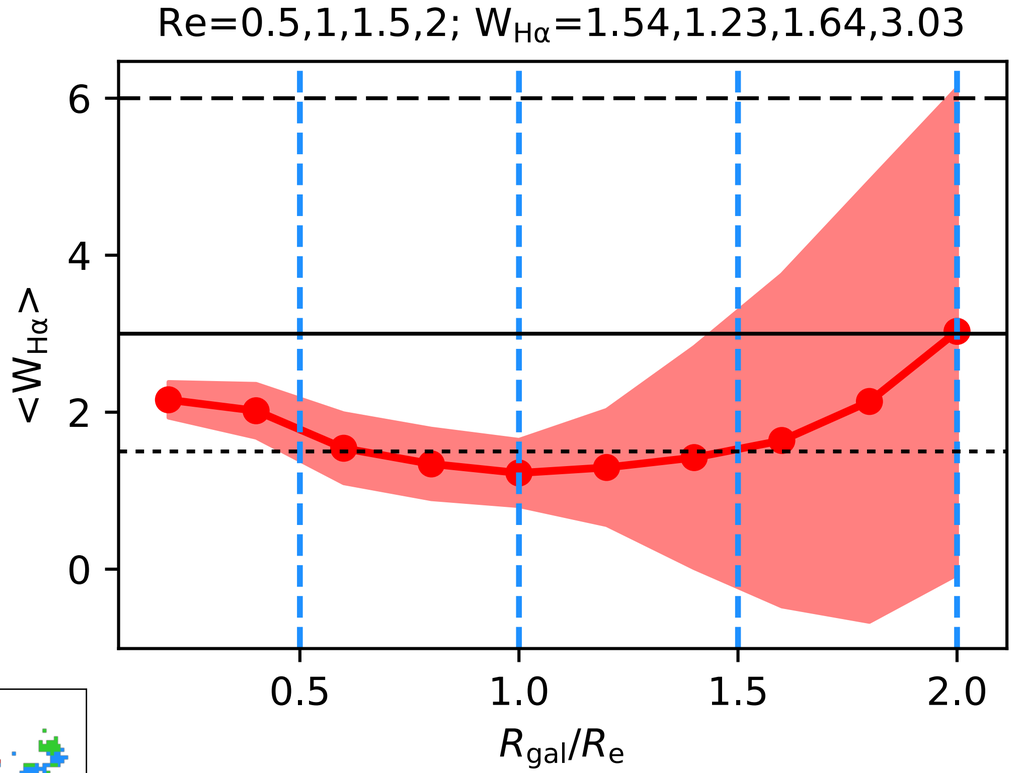
at $R_e < 0.5$

Kalinova et al., in preparation

EXAMPLE



LINER



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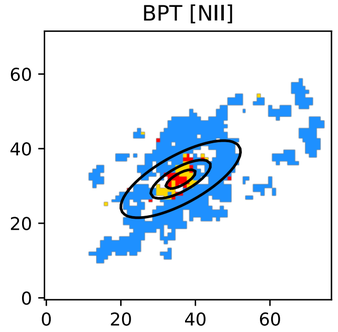
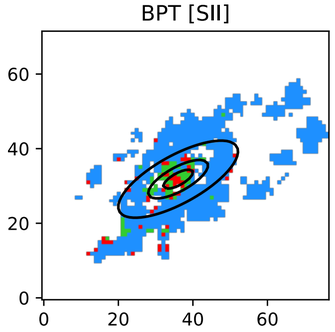
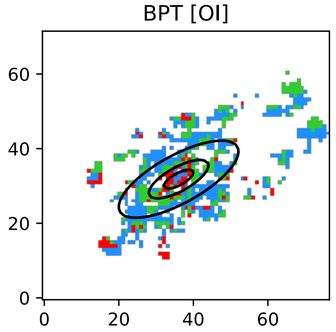
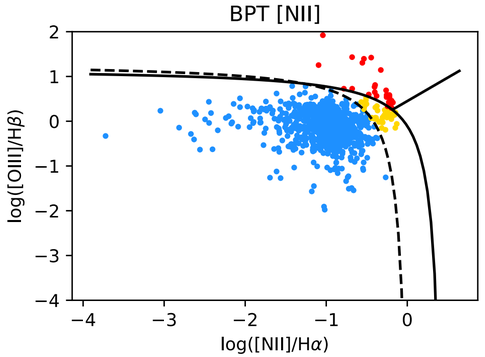
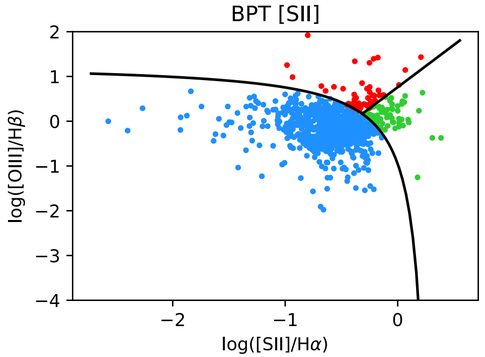
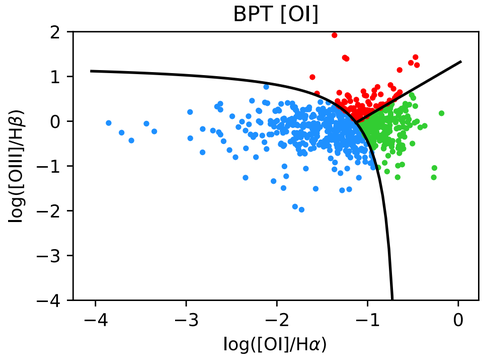










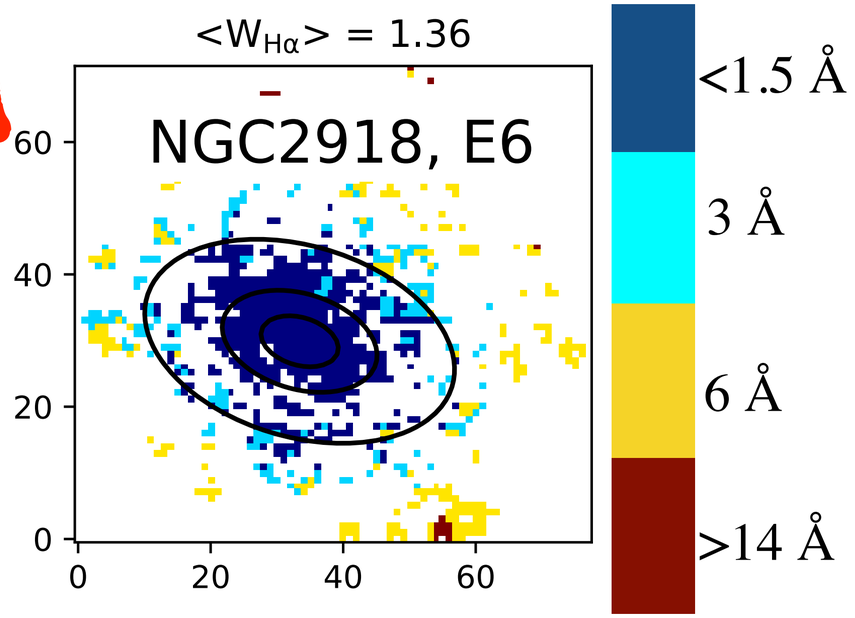


main criteria for LINER:

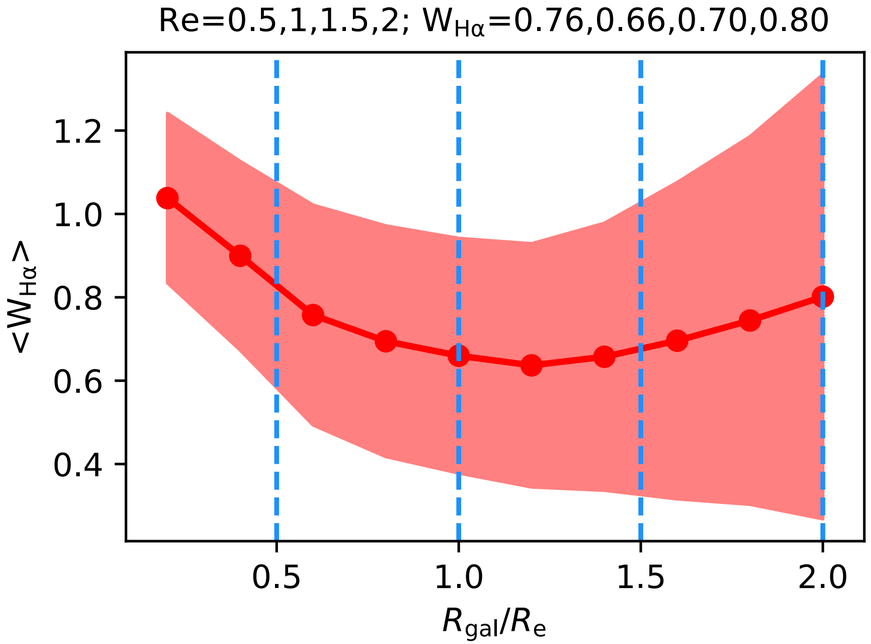
$W_{H\alpha}$ - below 3Å at the central parts (i.e., $R_e < 1.5$) & above 3Å in the outskirts (i.e., $R_e > 1.5$)

Kalinova et al., in preparation

EXAMPLE



LIER



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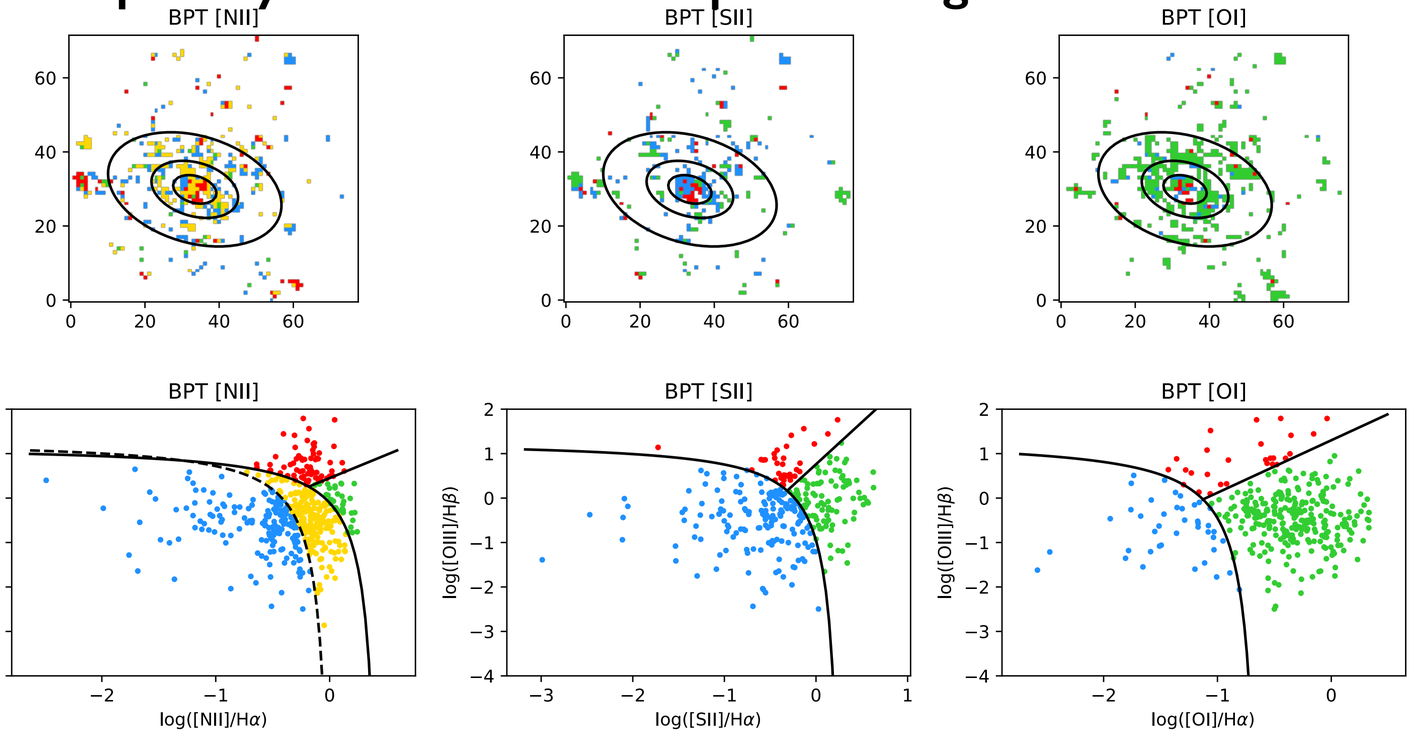

criteria for LIER:

$W_{H\alpha}$ - below 1.5Å at all radii

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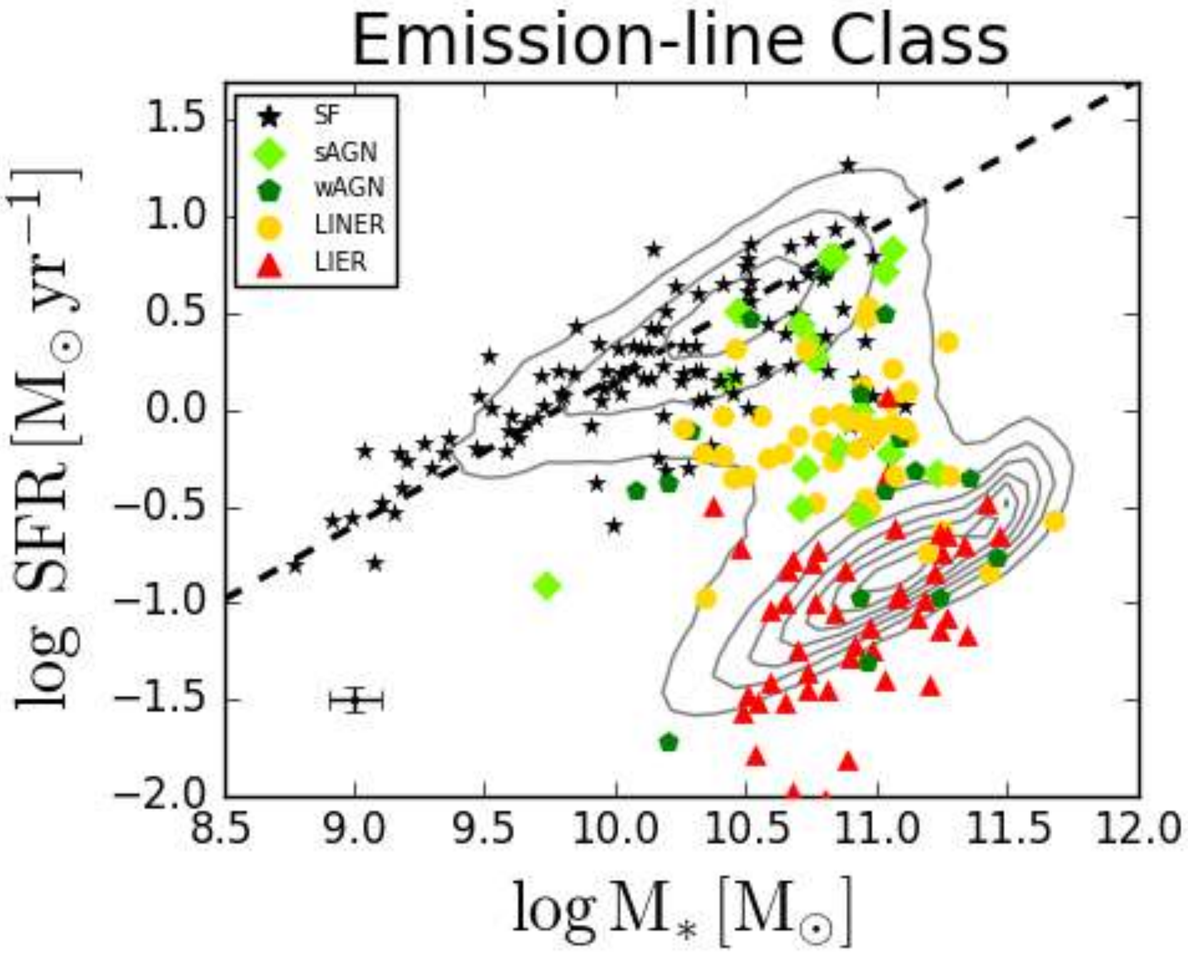
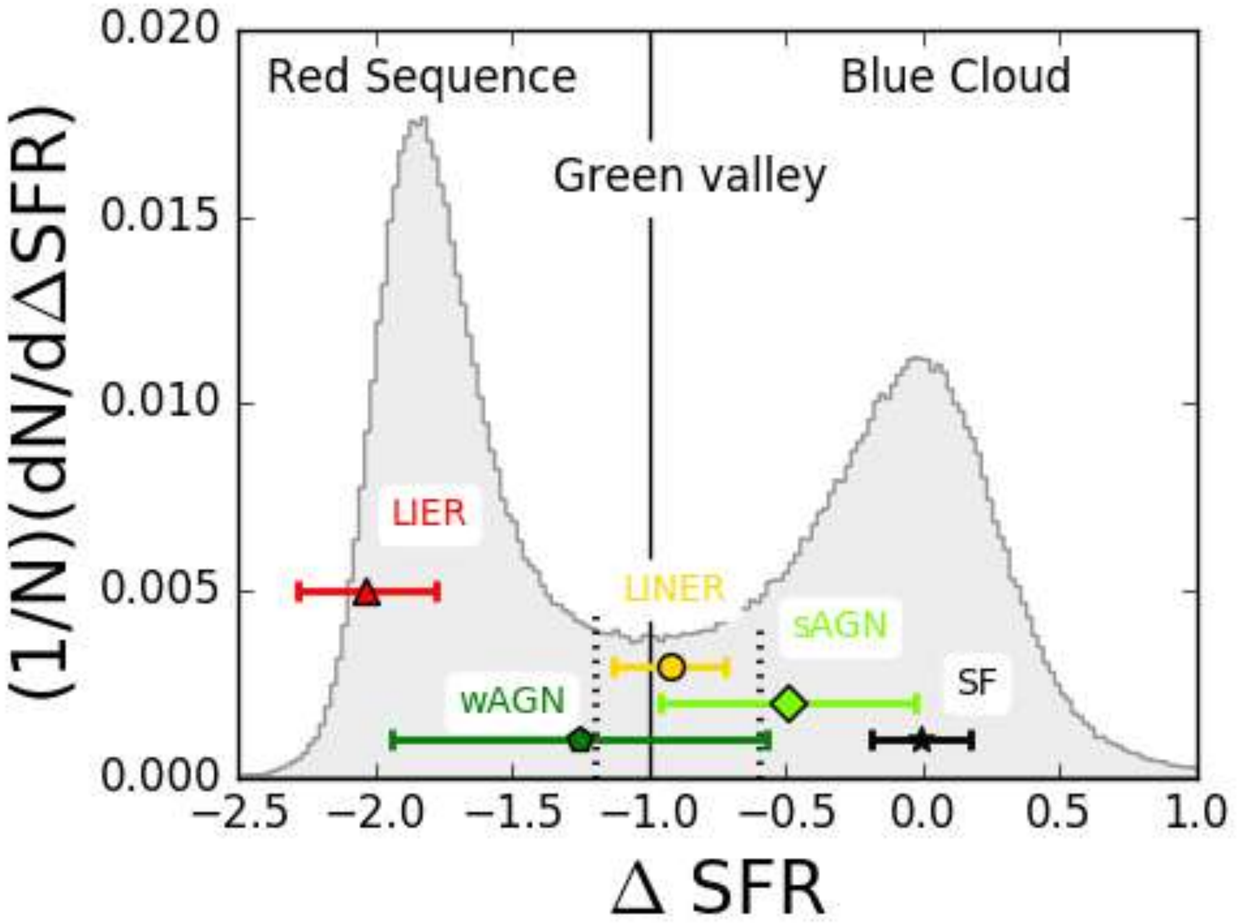
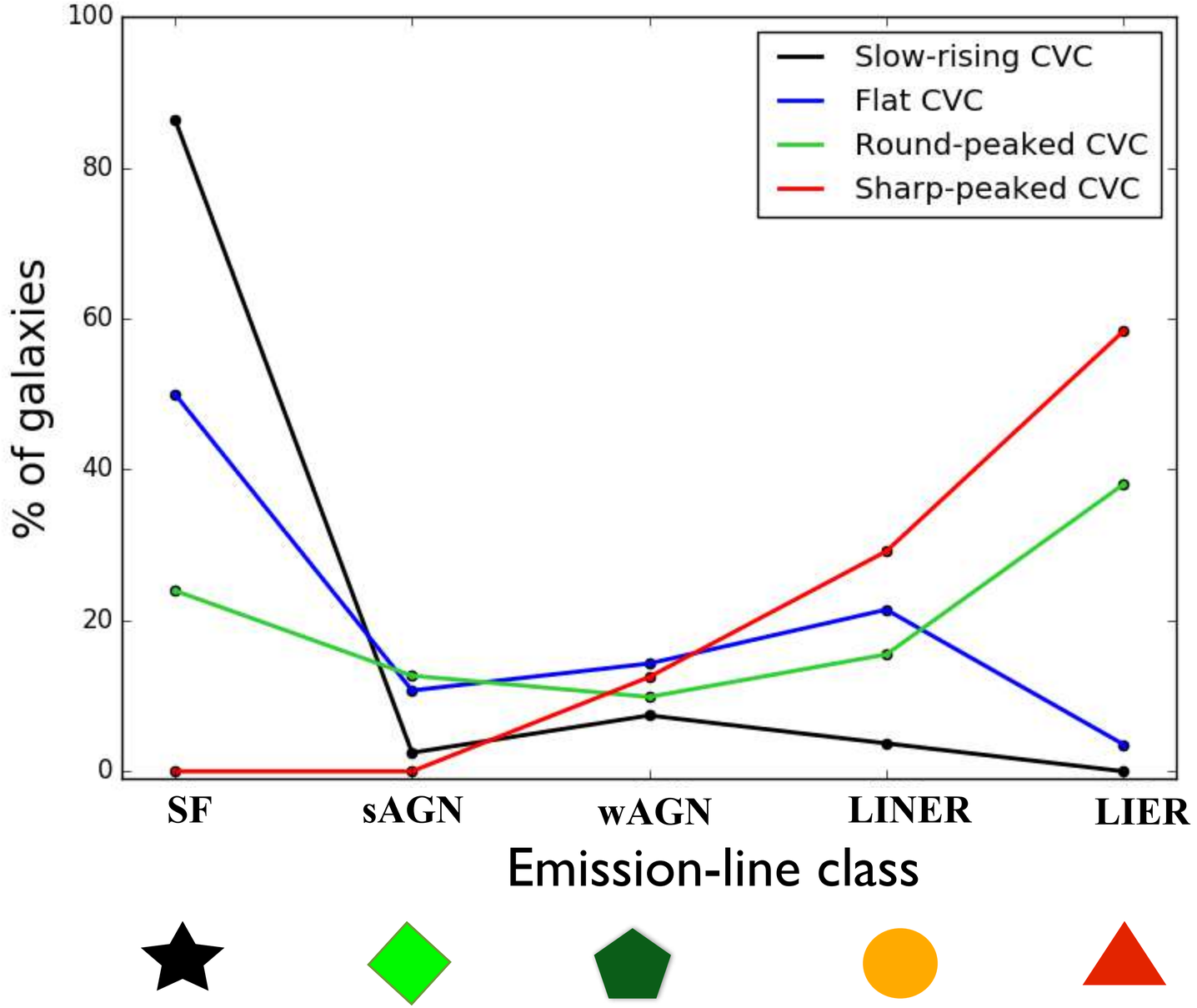
Emission-line classification of 231 CALIFA galaxies





SF, LINER and LIER galaxies occupy distinct domains on SFR-M* plane - the Blue cloud, Green valley and Red sequence, respectively

Emission-line classification vs. CVC classification for 238 galaxies



Star-forming galaxies tend to have slow-rising and Flat CVCs

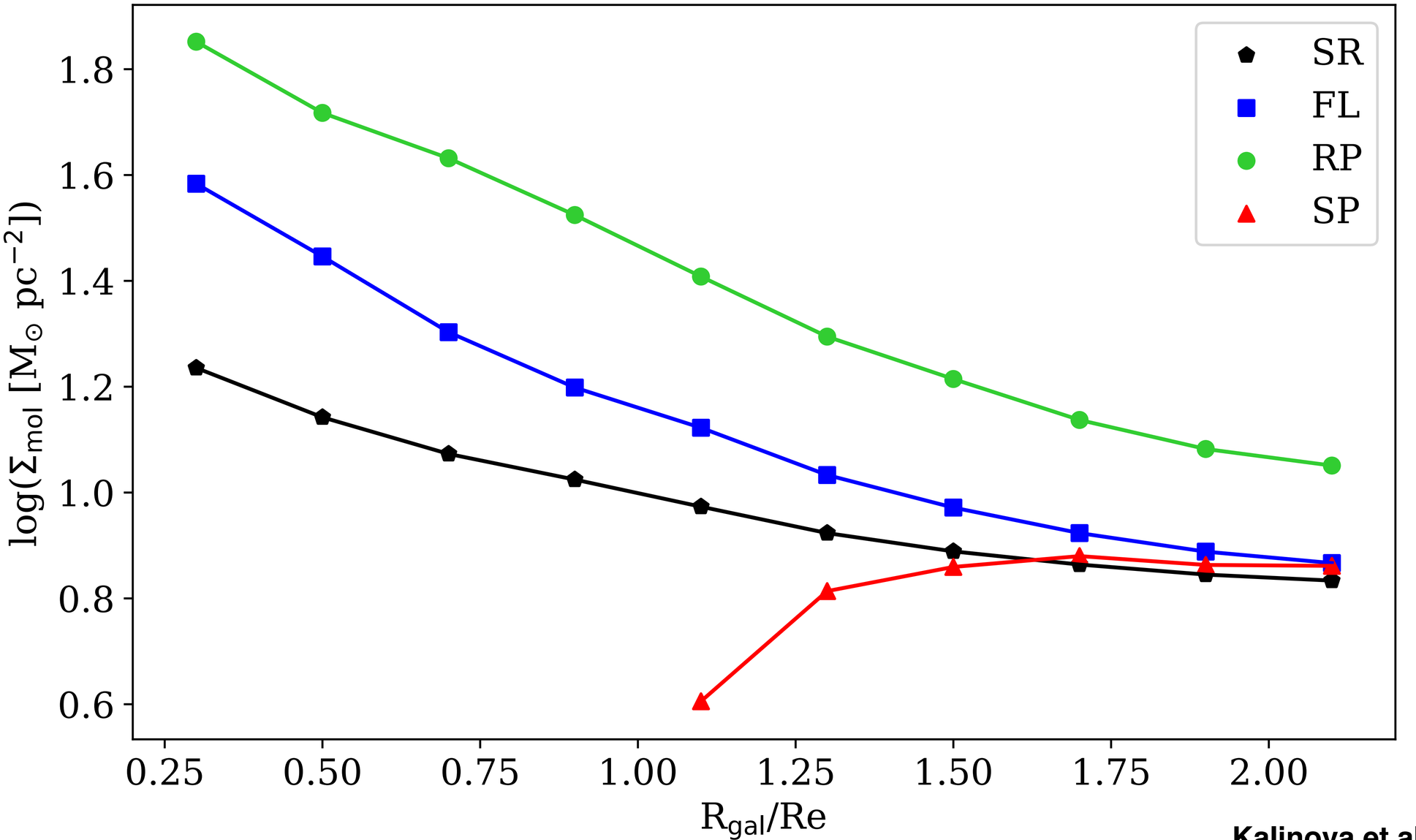
Strong-AGN galaxies tend to have Flat and Round-peaked CVCs

LIER galaxies tend to have Round- and Sharp-peaked CVCs

Kalinova et al., in preparation

Preliminary results

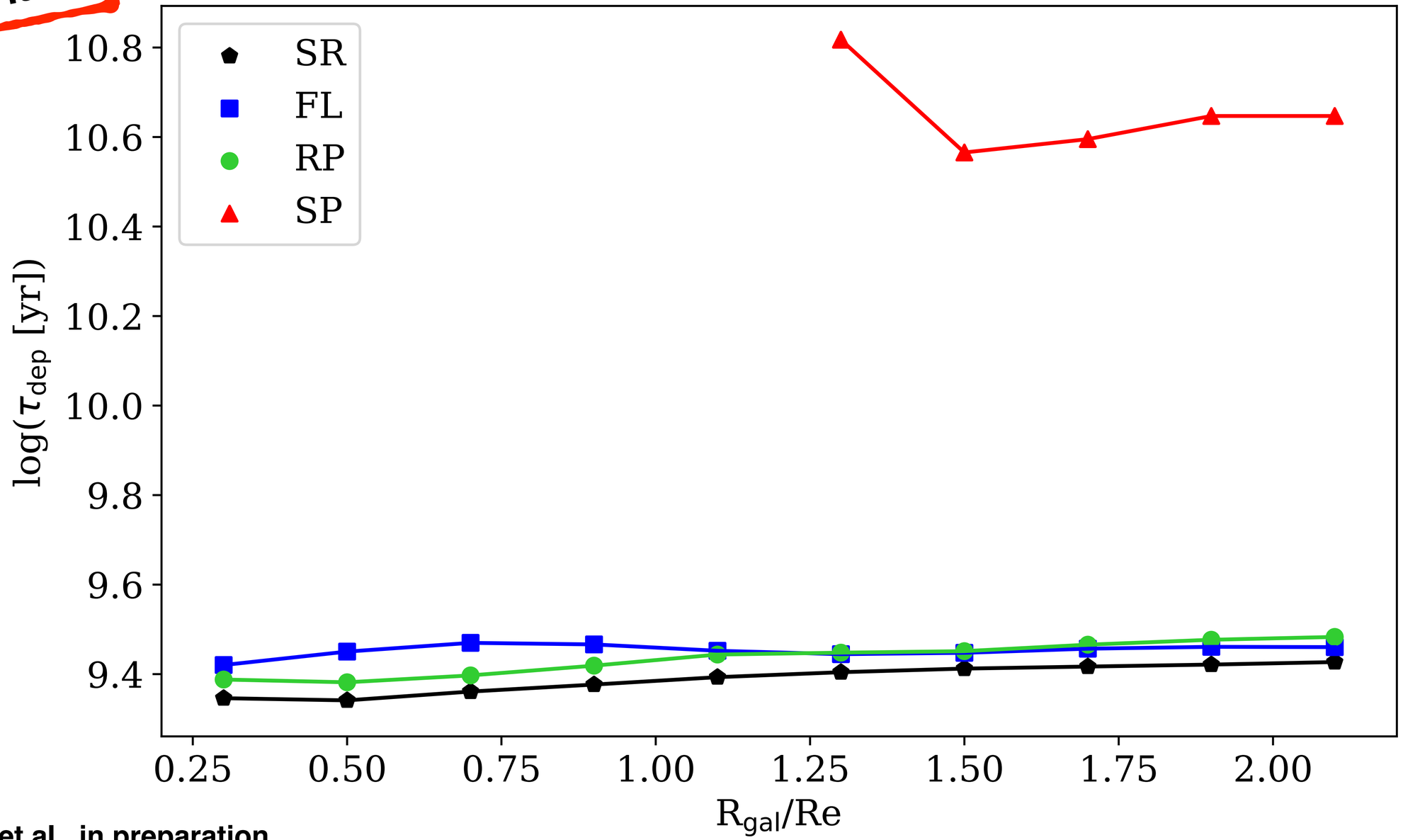
CVC classification of 85 EDGE galaxies: Molecular gas mass surface density



Kalinova et al., in preparation

CVC classification of 85 EDGE galaxies: Depletion time

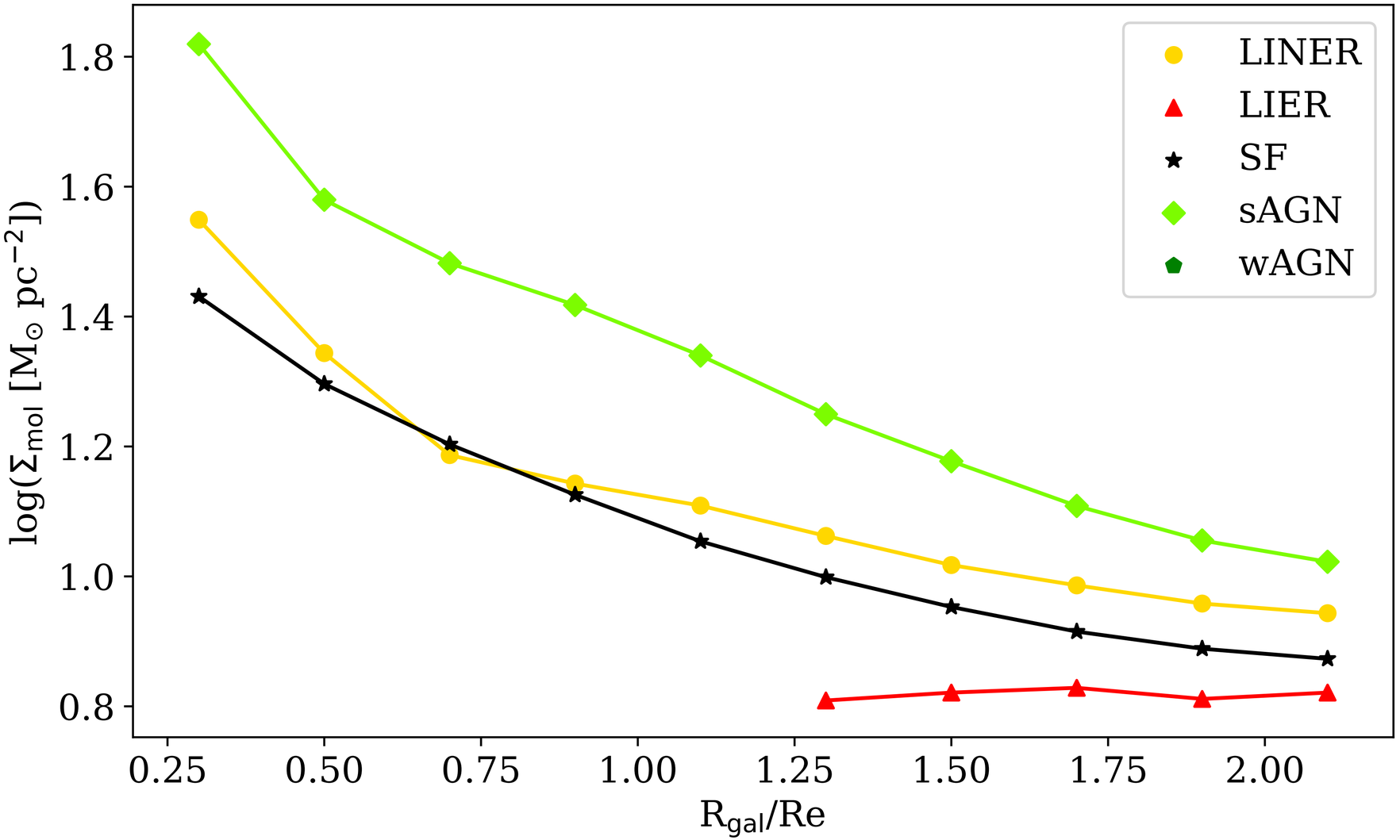
Preliminary results



Kalinova et al., in preparation

Preliminary results

Emission-line classification of 117 EDGE galaxies: Molecular gas mass surface density

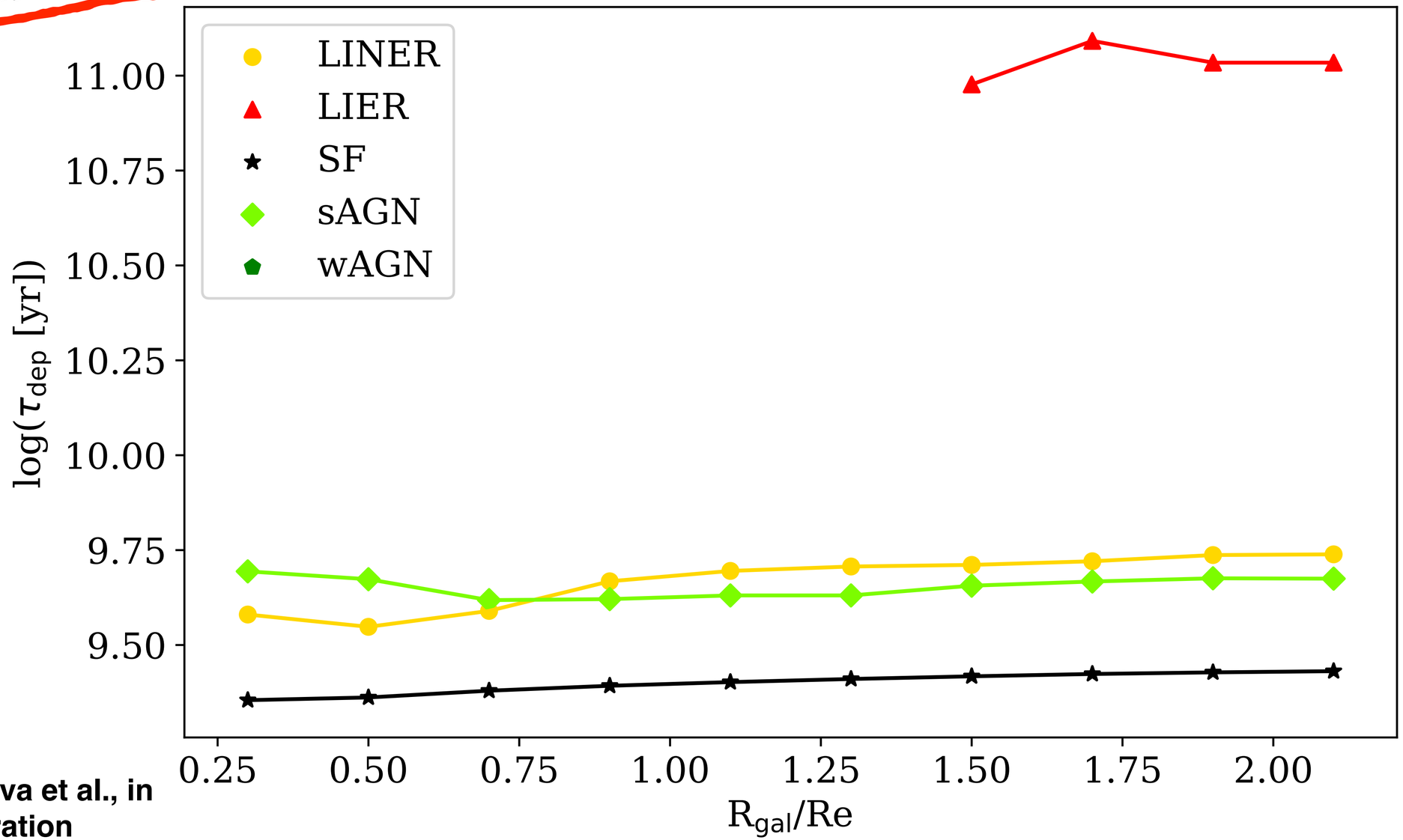


Kalinova et al., in preparation

wAGN and Mergers are not shown due to low statistical significance

Emission-line classification of 117 EDGE galaxies: Depletion time

Preliminary results



Kalinova et al., in preparation

Next step: Gathering HI, CO and [CII] data for CALIFA/EDGE sample of galaxies

HI data

Effelsberg (PI: Kalinova);
100 h granted (on-going)

VLA (PI: Kalinova; Blitz; Wong)
observed 2 galaxies in C-conf; 10 galaxies in B-conf; applied for a large program

GBT (PIs: Wong, Utomo);
100 h granted (completed)

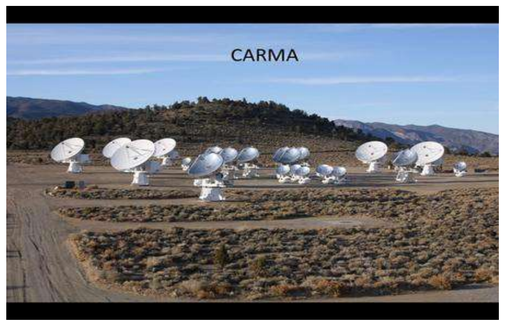
GMRT (PI: Kalinova)
ongoing pilot project for 3 galaxies

CO and [CII] data

To study Dark Matter Halo, SFE and density profiles from the Blue cloud to the Red sequence

APEX (PI: Colombo)
130 h (completed) + 140h (on-going)

CARMA (Bolatto et al. 2017)
177 galaxies observed 800 h granted

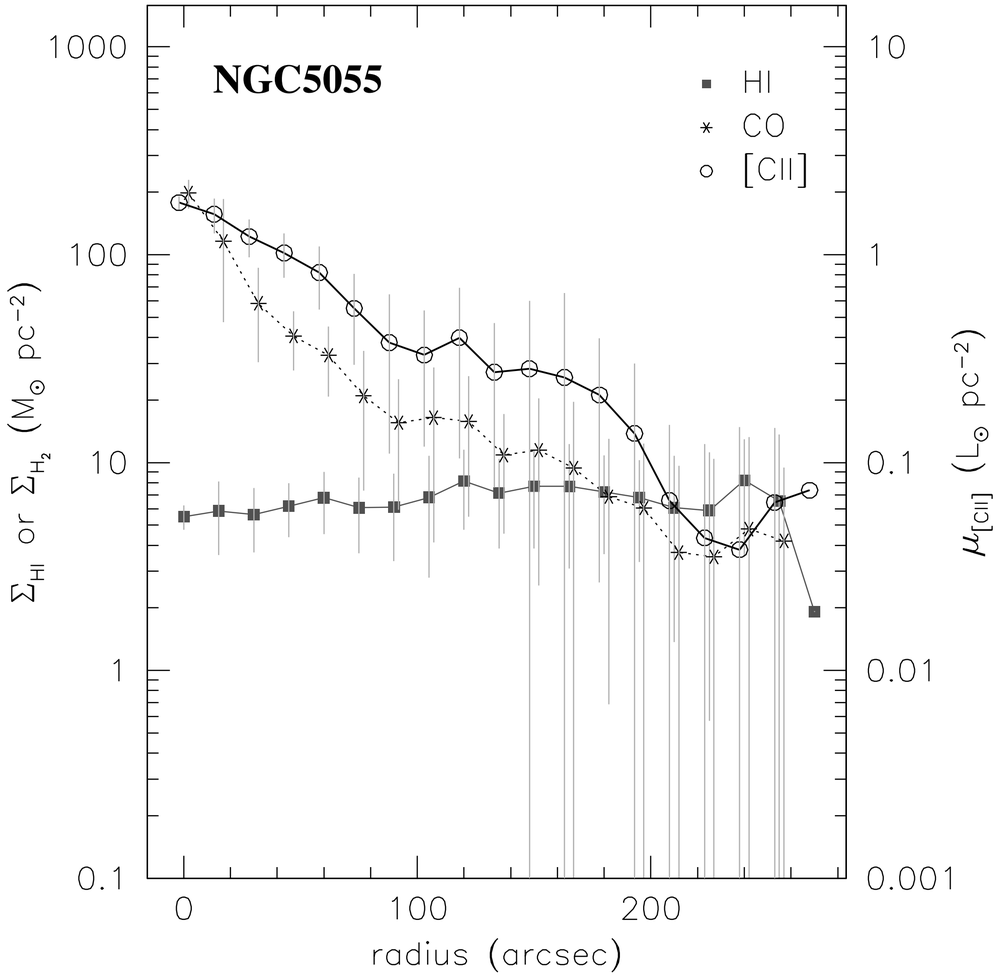


ALMA (PI: Bolatto)
plan for a large program

SOFIA (PI: Bolatto)
on-going project

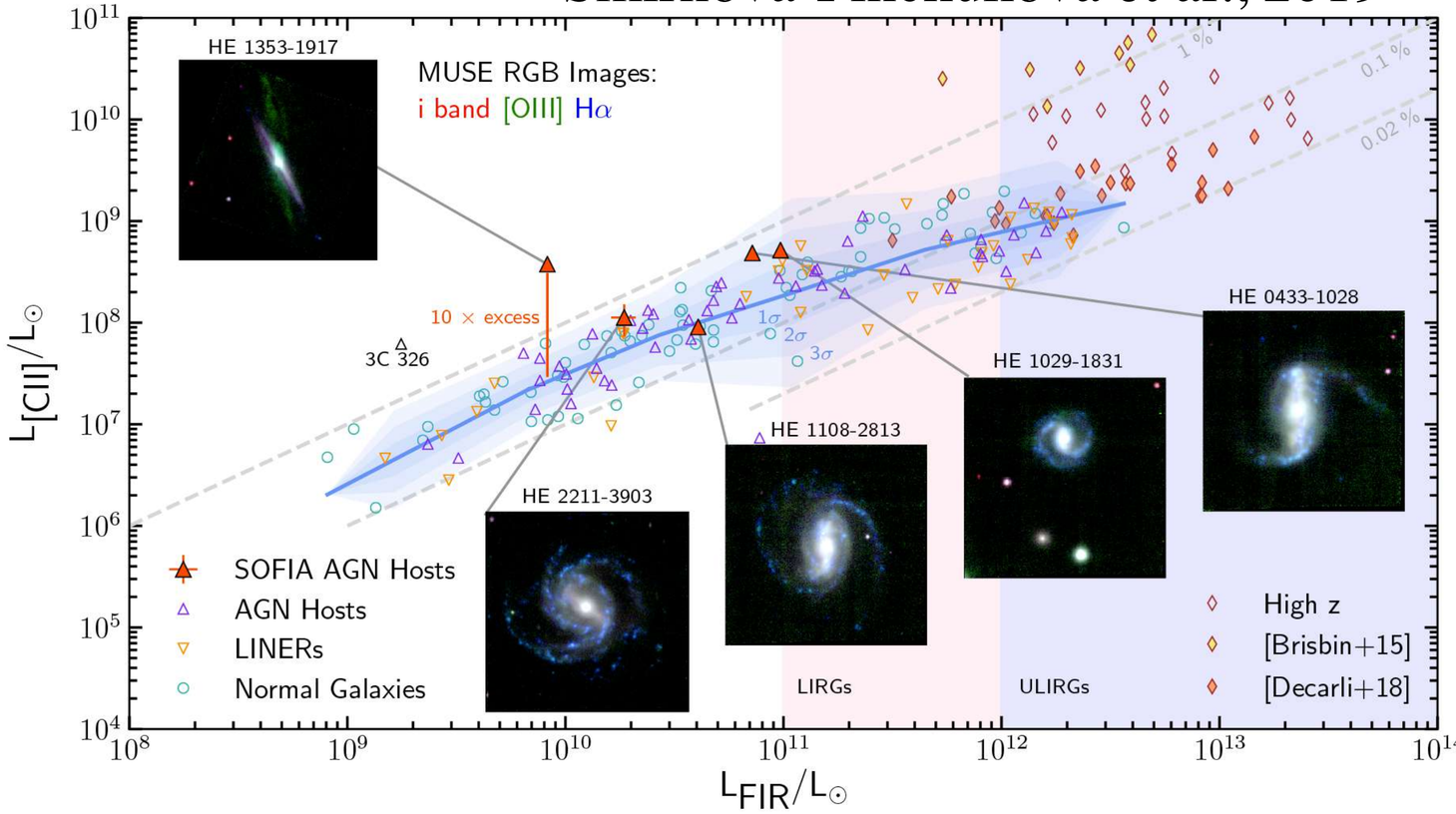
To understand dynamics, formation and evolution of galaxies across cosmic time - [CII] observations of nearby galaxies are needed

de Blok et al., 2016



[CII] integrated spectrum resembles that of the CO more than that of the HI

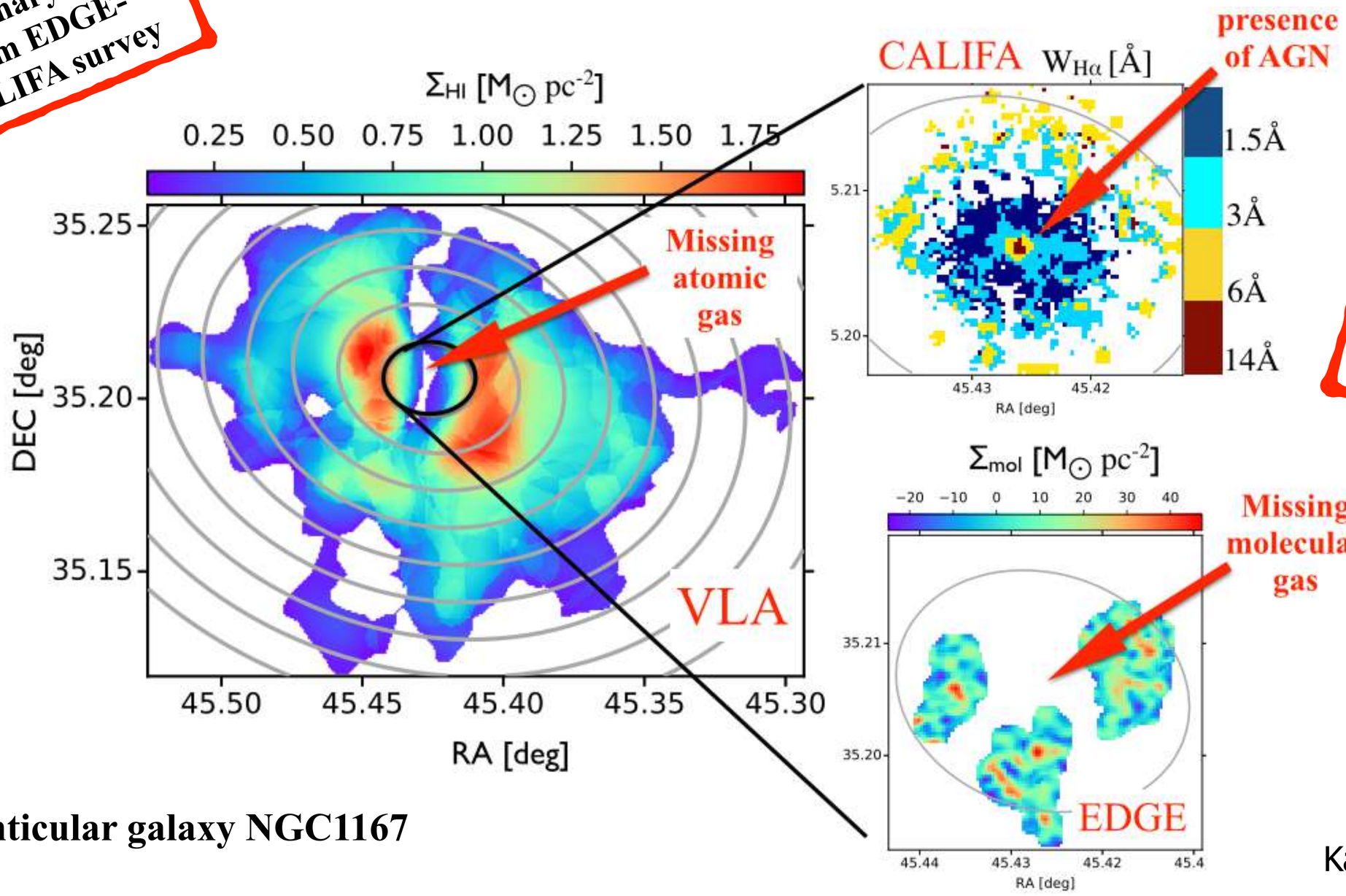
Smirnova-Pinchukova et al., 2019



[CII] line excess in high-redshift galaxy HE 1353–1917 is due to the impact of the AGN that drives a massive multiphase outflow on kiloparsec scales

The “smoking gun” of an AGN star-formation quenching

Preliminary results from EDGE-CALIFA survey



Synergy between highly-resolved IFU, CO and VLA data

lenticular galaxy NGC1167

Kalinova et al., in prep

The “smoking gun” of an AGN star-formation quenching

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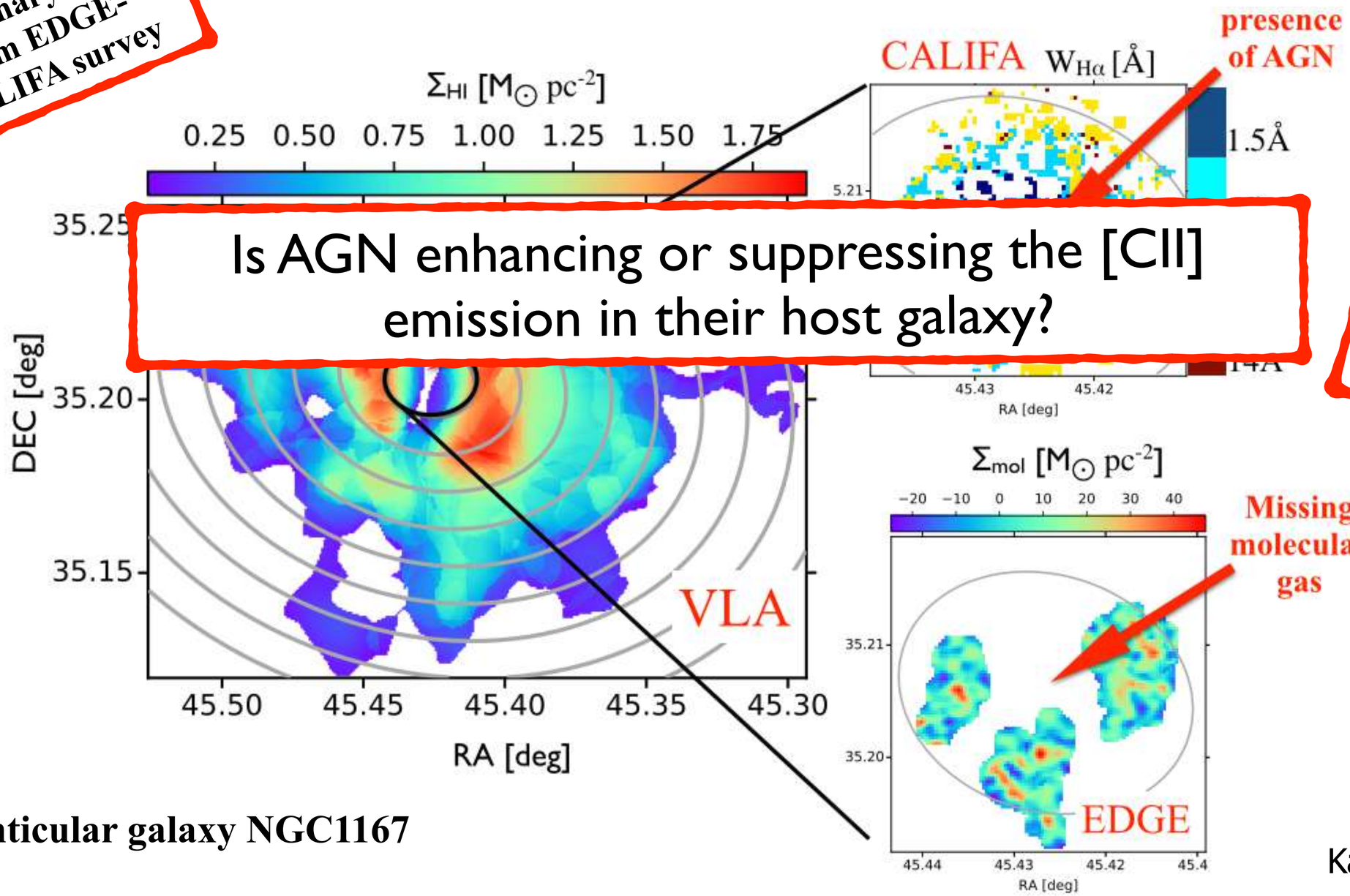


Is AGN enhancing or suppressing the [CII] emission in their host galaxy?

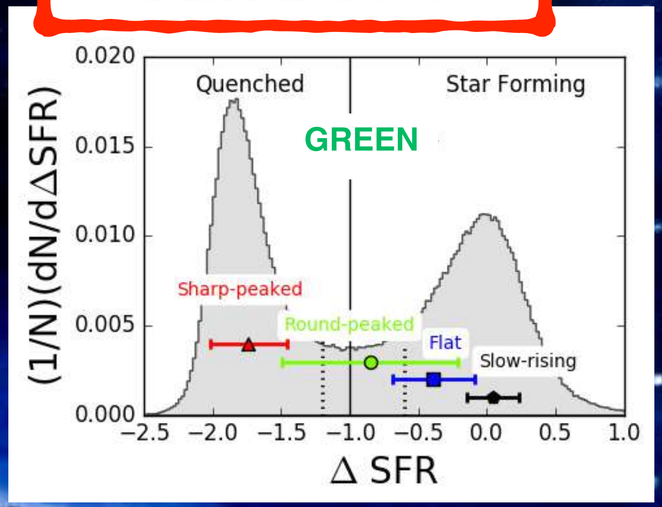
Synergy between highly-resolved IFU, CO and VLA data

lenticular galaxy NGC1167

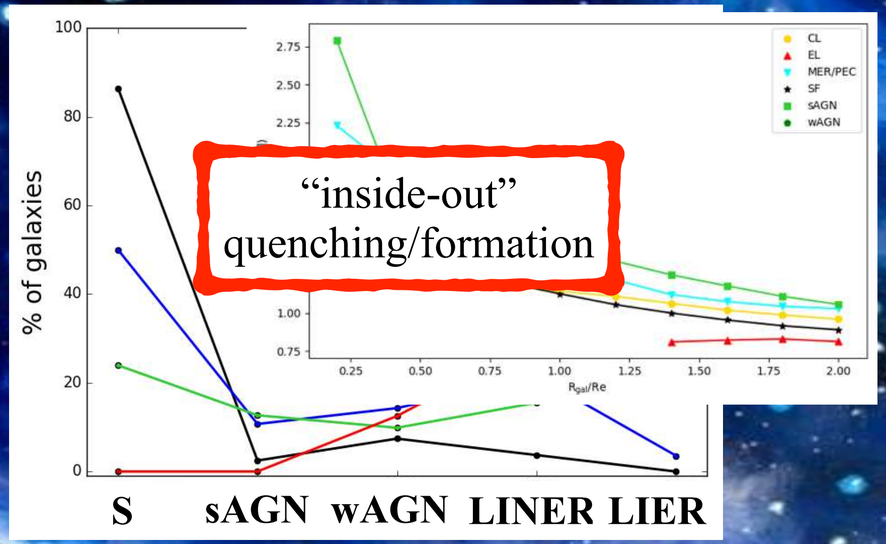
Kalinova et al., in prep

Conclusions

evolutional sequential transition of CVC



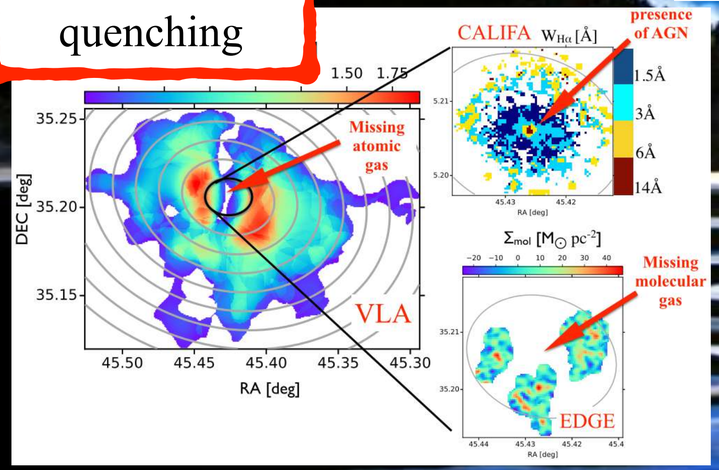
CVC classes show an **evolutional sequential transition (SR-FL-RP-SP)** with an increasing central mass concentration.



"inside-out" quenching/formation

The CVC (i.e. Dynamical) classification of nearby galaxies supports the **"inside-out"** quenching and formation scenarios.

AGN SF quenching



Proto-galaxy merging or secular evolutional processes increase the mass of the galaxies from disc to ellipsoid, **lead to a high central mass-concentration** to form a massive BH, whose activity **dispersed** the angular-momentum-carrying diffuse baryon, to **quench star-formation** in an early epoch of galaxy formation history.

image credit: Kathryn Beals